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Sulfoxide and 3,4-Methylenedioxybenzyl *n*-Propyl Ether in Pyrethrum and Allethrin Mixtures as House Fly Sprays

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A quantitative comparison of the effects of several synergists in pyrethrum and allethrin fly sprays has been reported by Gersdorff *et al.* (1951). A similar comparison has been made of the effects in mixtures with these insecticides of two more adjuncts, a technical product known as sulfoxide and the chemically pure compound 3,4-methylenedioxybenzyl *n*-propyl ether. The first material is the *n*-octyl sulfoxide of isosafrole, found promising by Synerholm *et al.* (1947) as a synergist with pyrethrins. Starr (1950) reported excellent results in many tests with this material[1] against house flies and cockroaches. The second material has shown some synergistic activity in mixtures with pyrethrins (La Forge *et al.* 1947) and with scabrin (Gersdorff & Mitlin 1952). It is hereafter referred to as the benzyl propyl ether.

MATERIAL AND METHODS.—The sample of allethrin used was of a high degree of purity, 94 per cent by the hydrogenolysis method. In the sample of pyrethrum extract 54 per cent of the total pyrethrins consisted of pyrethrin I and cinerin I as determined by the mercury-reduction method.

Sprays of the two insecticides alone and and mixed with each of the adjuncts and also sprays of the adjuncts alone were prepared by dissolving them in refined kerosene at concentrations determined according to preliminary tests. Because sulfoxide was not completely soluble in refined kerosene, 5 per cent of acetone (by volume) was used as an auxiliary solvent. This amount of acetone in pyrethrum sprays causes no noticeable increase in mortality. The mixed sprays were prepared only in the proportion of 5 parts of adjunct to 1 part of toxicant, as suggested by the manufacturer of sulfoxide for mixtures of that material with pyrethrins.

The tests were made by the turntable method on laboratory-reared adult house flies, *Musca domestica* L. Knockdown and mortality were determined in replicated tests, approximately 100 flies averaging 2.5 to 3.5 days in age being used in each test.

To evaluate relative toxicity and determine the precision of the estimates, the mortality data were subjected to probit analysis by the maximum-likelihood method as described by Finney (1947).

MORTALITY AND KNOCKDOWN.—The results of the tests are assembled in table 1. comparison of mortalities in conjunction with concentrations indicates increased potency of the mixed sprays above that expected, but not so pronounced for the benzyl propyl ether as for the sulfoxide mixtures. However, the decision as to the significance of the increase in potency and its measurement, depend on further analysis.

The knockdown of flies was of high order with all mixtures. Only with the allethrin mixtures at the lowest concentration was there any appreciable falling off in the 25-minute count. This is a reflection of the slower rate of initial paralysis with allethrin than with pyrethrins, Although the adjuncts caused some knockdown at high concentrations, at the low concentrations used in the mixtures they did not appear to contribute to the knockdown effect.

EVALUATION OF RELATIVE EFFECTS.—To put the relationships on a quantitative

[1] Sulfox-cide.

Table 1.—Mortality and knockdown of house flies caused by kerosene sprays selected to study the comparative effect of pyrethrum synergists in pyrethrum and allethrin mixtures. Nine replicates.

Material	Concentration (mg. per ml.)			Knockdown in 25 Minutes (per cent)	Mortality in 1 Day (per cent)
	Insecticide	Adjunct	Insecticide Equivalent[1]		
Sulfoxide	—	160.0	—	28	63.1
	—	80.0	—	28	48.4
	—	40.0	—	23	31.4
	—	20.0	—	32	22.2
Pyrethrins+sulfoxide	0.500	2.50	0.550	100	94.9
	.250	1.25	.275	100	69.6
	.125	0.625	.137	99.6	34.4
	.0625	.313	.0687	95	22.7
Allethrin+sulfoxide	1.00	5.00	1.038	100	97.0
	0.500	2.50	.519	99.7	79.4
	.250	1.25	.259	98.6	40.8
	.125	0.625	.130	73	14.4
"Benzyl propyl ether"	—	160.0	—	97	58.9
	—	80.0	—	64	19.1
	—	40.0	—	32	5.1
Pyrethrins+the ether	2.00	10.0	2.125	100	76.2
	1.00	5.00	1.062	99.6	55.4
	0.500	2.50	0.531	99.9	20.5
	.250	1.25	.266	98.9	17.0
Allethrin+the ether	1.00	5.00	1.024	99.8	86.0
	0.500	2.50	0.512	98.8	59.0
	.250	1.25	.256	92	20.7
	.125	0.625	.128	61	4.8
Pyrethrins	8.00	—	—	100	92.3
	4.00	—	—	100	82.8
	2.00	—	—	100	53.0
	1.00	—	—	100	30.2
Allethrin	2.00	—	—	100	89.4
	1.00	—	—	100	64.1
	0.500	—	—	98	35.3
	.250	—	—	93	19.9

[1] Based on the relative toxicities of the adjuncts as given in table 2.

Table 2.—Evaluation of relative effects in the toxic action of the adjuncts in mixtures with pyrethrins and allethrin.

Material	LC-50 (mg. per ml.)		Relative Standard Error of LC-50 (Per Cent)	Ratio of Toxicity to—					Log of Ratio on Equivalent Basis to Corresponding Insecticide
				Pyrethrins			Allethrin		
	Original Basis	Insecticide Equivalent		Original Basis	Insecticide Content	Insecticide Equivalent	Original Basis	Insecticide Equivalent	
Pyrethrins	1.744 *W*	1.744	8.76	1.00	1.0	1.0	0.378	—	—
Pyrethrins plus —Sulfoxide	0.1467+0.7335	0.1613	8.48	—	11.89	10.81	—	—	1.034
"Benzyl propyl ether"	.8981+4.491	.9541	8.05	—	1.94	1.83	—	—	0.262
Allethrin	.6591	.6591	7.99	2.646	2.65	2.65	1.0	1.0	—
Allethrin plus —Sulfoxide	.2738+1.369	.2841	8.98	—	6.37	6.14	—	2.32	.365
"Benzyl propyl ether"	.4479+2.240	.4585	8.72	—	3.89	3.80	—	1.44	.158
Sulfoxide	87.82	—	4.67	0.01986	—	—	0.00751	—	—
Benzyl propyl ether	139.9	—	6.62	.01247	—	—	.00471	—	—
Minimum required to demonstrate synergism	—	—	—	—	—	1.27, 3.37[1]	—	1.27	.104

[1] The first ratio is that required for pyrethrins mixtures, the second for allethrin mixtures when pyrethrins is the base.

basis, provisional regression lines were fitted graphically from the data. Weighted regression equations were then computed by the maximum-likelihood method.

The statistically fitted lines approximated very closely the provisional lines. Those for the insecticde-containing sprays had slopes ranging from 2.01 to 3.25 probits per unit log concentration. The individual chi-square, with but 2 degrees of freedom, in most cases gave a significant value as a measure of departures from the regression line. However, the probit-log concentration graphs gave no suggestion of any systematic deviations from linearity. The heterogeneity was therefore allowed for by multiplying all variances by the heterogeneity factor (Finney 1947). Rather than use separate factors each with but 2 degrees of freedom and therefore of low precision, the chi-square values were pooled. This is permissible because of the comparability of the tests, the entire series of sprays being tested with each population of flies, and the similarity of the slopes. In most comparisons of allethrin with pyrethrins by this method the regression line for the former is significantly steeper than that for the latter. In some, however, the difference is so small that it is not statistically demonstrated in a reasonable number of tests. This is the case in the present study. The slopes of the individually fitted lines with their standard errors (a heterogeneity factor being used for each) were 2.324 ± 0.240 for allethrin and 2.178 ± 0.202 for pyrethrins.

A study of the experimental errors of the regression coefficients for the insecticides and their mixtures justified the fitting of parallel lines. The generalization procedure involved the estimation of a common regression coefficient as described by Finney (1947). This was found to be 2.497 ± 0.123. The equations for the generalized lines for the insecticides and their mixtures are given below. Those for the individual lines for the two adjuncts, not included in the generalization because the tests with them gave information only on the lower half of their course of toxic action, are also given. All equations show the relationship between the transformed functions of the variates, mortalities being expressed in probits and concentrations in logarithms of concentrations in milligrams per deciliter. Those for the mixtures are based on the expression of concentration in terms of insecticide content only.

Pyrethrins	$Y=2.497X+0.5983$
Pyrethrins+sulfoxide	$Y=2.497X+2.0869$
Pyrethrins+"benzyl propyl ether"	$Y=2.497X+0.1216$
Allethrin	$Y=2.497X+0.4571$
Allethrin+sulfoxide	$Y=2.497X+1.4100$
Allethrin+"benzyl propyl ether"	$Y=2.497X+0.8763$
Sulfoxide	$Y=1.248X+0.8000$
"Benzyl propyl ether"	$Y=3.220X-8.3478$

In the analysis of the pooled chi-square, the chi-square measuring departure from parallelism was significant. However, significant residual heterogeneity was also known, and the two mean squares were not significantly different. Therefore, it appears that heterogeneity between populations of flies has increased both chi-squares. This was highly probable, since there were differences in age, and therefore in resistance, between some populations. The mean square for residual heterogeneity was used as a heterogeneity factor in the calculation of variances for the common regression coefficient and the LC-50's determined below.

The evaluation of relative effects is summarized in table 2. Relative toxicity was determined on the basis of insecticide equivalents and also on the basis of actual insecticide content. Determination of equivalents is necessary to demonstrate synergism and measure its intensity when the adjuncts themselves are toxic. The insecticide equivalent of a mixture is the sum of the actual amount of the insecticide and the insecticide equivalent of the adjunct. The latter is the product of the actual amount of adjunct and its toxicity relative to the insecticide. To show a significant increase in toxicity of the mixture over that expected, comparison with the standard error is necessary. For simplicity the errors of the LC-50's are reported as relative standard errors. From these the minimum requirement to demonstrate synergism was calculated. The evidence of synergism in all four mixtures is pronounced.

DISCUSSION OF EFFECTS.—From the standpoint of effectiveness of mixtures containing 1 part of insecticide to 5 parts of synergist, the mortality results show that with both insecticides sulfoxide is the better synergist. They also show that with sulfoxide as the synergist pyrethrium is

the better insecticide, but with the benzyl propyl ether allethrin is the better. These relationships are expressed quantitatively in columns 6 and 7 of table 2.

As also shown in table 2, the benzyl propyl ether synergized allethrin but moderately, the mixture being 1.44 as toxic as allethrin. In pyrethrum mixtures it was a stronger synergist, the mixture being 1.83 as toxic as pyrethrins. Sulfoxide was the more powerful synergist with each insecticide, the relative toxicity being 2.32 as much as the expected when allethrin was used and 10.81 when pyrethrins was used. Thus, the intensity of synergism with sulfoxide was 4.7 and with the benzyl propyl ether 1.3 as great in the pyrethrum mixtures as in the allethrin mixtures.

Two of the synergists included in the previous study (Gersdorff *et al.* (1951) were piperonyl butoxide and synergist (MGK)-264. Their effects were determined in mixtures containing 10 parts of synergist to 1 part of insecticide. With this difference in the two studies being noted, it may be pointed out that the toxicity ratios given in table 2 place sulfoxide in the same class of synergists as piperonyl butoxide for both insecticides and the benzyl propyl ether in the same class as MGK-264.

Allethrin was more toxic than pyrethrins. Therefore, if the intrinsic toxic value of the synergists, which was negligible, is ignored and comparison is made on the basis of insecticide content, the relative toxicities of the insecticidal materials are in the following ascending order: Pyrethrins (1), pyrethrins plus the benzyl propyl ether (1.9), allethrin (2.6), allethrin plus the benzyl propyl ether (3.9), allethrin plus sulfoxide (6.4), and pyrethrins plus sulfoxide (11.9). The order is the same and the ratios but slightly lower on the basis of insecticide equivalent.

SUMMARY.—The comparative effect of sulfoxide and 3,4-methylene-dioxybenzyl *n*-propyl ether in oil sprays containing either allethrin or pyrethrins in the proportion of five times as much adjunct as insecticide was determined in tests against the house fly, *Musca domestica* L., by the turntable method.

The two pyrethrum synergists also synergized allethrin, but to a lesser degree. The intensity of synergism with sulfoxide was 4.7 and with the benzyl propyl ether 1.3 as great in the pyrethrum as in the allethrin mixtures. The mixture of sulfoxide and pyrethrins was 10.81 as toxic as pyrethrins, whereas the mixture of sulfoxide and allethrin was but 2.32 as toxic as allethrin. The mixture of the benzyl propyl ether and pyrethrins was 1.83 as toxic as pyrethrins, whereas the mixture of the benzyl propyl ether and allethrin was 1.44 as toxic as allethrin.

However, when consideration is given to the greater toxicity to the house fly of allethrin as compared with pyrethrins as well as synergistic effect, the relative effectiveness of the insecticidal materials falls in the following ascending order, whether the evaluation is based on principal toxicant only or on insecticide equivalent: Pyrethrins, pyrethrins plus the benzyl propyl ether, allethrin, allethrin plus the benzyl propyl ether, allethrin plus sulfoxide, and pyrethrins plus sulfoxide. The last mixture is nearly 12 times as toxic as pyrethrins on the first basis and nearly 11 times on the second.

Knockdown of flies was of high order with all mixtures.

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Tests with Insecticide Formulations for the Destruction of Cattle Grubs

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Following the work of Wells, *et al.* (1922) with derris powder, many attempts have been made in an effort to find materials superior to rotenone for the destruction of cattle grubs. Despite the limitations of rotenone, particularly from the standpoint of limited residual effectiveness, it remains today without equal for the purpose mentioned. In recent years, attention has been briefly directed towards the chlorinated hydrocarbon insecticides, none of which has shown effectiveness against ox-warbles, Telford 1947; Furman & Douglas 1948; Scharff 1950; Knipling 1951. The use of rotenone synergists also has been unsuccessful. (Douglas & Furman 1949; Scharff 1950). Bishopp *et al.* (1926) suggested the inclusion of soap in those derris formulations requiring a detergent; soap has not been excelled by any of the newer detergents for use in facilitating the application of rotenone washes to cattle.

The tests described in this paper contribute to the rapidly growing literature on the history of failure to develop, within the last few years, a completely satisfactory larvicide against cattle grubs. All the materials used were selected in the hope that they might prove superior, equal or complementary to rotenone.

Materials and Methods.—The tests were performed on cattle at the Central Substation of the South Dakota Agricultural Experiment Station located at Highmore, South Dakota. Tests Nos. 1 through 7 were performed during April, 1950, and the remaining 6 in April of 1951. The animals treated were 12- to 14-month-old Hereford calves, each weighing about 400 pounds, and all rather uniformly infested with third instar *Hypoderma bovis* larvae. The larvae of *Hypoderma lineatum* found in these animals were so few that they are not included in the data presented. The second instar larvae of both species also were so few that their numbers are not considered in this work. A total of 88 calves were treated. Each insecticide formulation was applied to a group of not less than 4 nor more than 8 animals. The calves were restrained, usually 4 at a time, in a narrow chute, both at the time of treatment, and later, when all larvae found were extracted.

Of the several insecticidal formulations used in the series of tests described in this paper, only one was applied in the form in which it was prepared commercially. This material was a rotenone-piperonyl cyclonene aerosol, dispensed from a steel container or bomb. The 5-pound cylinder was of 4-pound capacity, and was carried by the operator much in the manner of a small knapsack sprayer. A two-foot length of flexible hose and a 12-inch curved copper extension tube equipped with a valve and nozzle, enabled the operator to direct the finely divided spray to the backs of the cattle. The nozzle was held at a distance of from 0.5 to 2 inches from the back, and was moved slowly over the dorsum in an effort to apply the aerosol fog upon every cyst opening. It was anticipated that the minute droplets, traveling at high velocity, would readily penetrate the small and partially occluded openings. The rate of delivery of the bomb was 180 mgs. of rotenone and 720 mgs. of cyclonene per minute. The temperature of the cylinder and its contents was approximately 70° F. at the time of use. Droplets of which the spray was composed were said by its manufacturer to be no larger than 20 microns in diameter. Application was of 60 seconds duration for each animal in Test No. 1, and 90 seconds in test 2.

The remaining insecticides were either dissolved or suspended in water warmed to 100° F., and applied to the backs of the animals in the form of washes. Each

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animal received a 500 cc. application of the liquid insecticide. Application was made by one operator who poured the liquid from a graduate as evenly as possible over the dorsum of each animal; simultaneously, another operator brushed the liquid into the haircoat and onto the skin. Palmetto brushes with stiff, 4-inch bristles were used for this purpose. The back of each animal was brushed vigorously for one minute.

The water used in the preparation of the washes was analyzed for hardness with the following results:

Total hardness (p.p.m.)	416.6
Total hardness (grains/gal.)	24.4
Caldium (p.p.m.)	114.5
Magnesium (p.p.m.)	27.2
Sodium (p.p.m.)	129.0

Evaluation of the effectiveness of the insecticidal formulations tested involved the extraction of all larvae from the subdermal cysts on the eighth or ninth day after application. In test 13, the interval was 8 days, while in all the others it was 9. Curved mosquito forceps were used in extracting the larvae. With jaws closed, the forceps were introduced into each opening, the jaws then opened wide momentarily to enlarge the hole, if necessary, and the grub removed gently so as to minimize damage to the parasite. In most instances it was possible to distinguish between live and dead grubs at once. The criteria denoting life or death in cattle grubs are not readily apparent, but there could be no cause for doubt when the grubs were found to be partially disintegrated, or extremely flaccid. When the larvae were normal in appearance and high in muscle tone, it became necessary to examine them more closely. In such instances, the aid of a hand lens was frequently required to reveal any movement which might indicate the existence of life.

RESULTS.—A summary of the effectiveness of the various formulations is given in the accompanying table. The efficacy of the materials tested is given on a percentage basis in terms of larval mortality.

As shown in tests nos. 1 and 2, the aerosol preparation was relatively ineffective against cattle grubs. It was found that the dense, matted haircoats of the Hereford calves broke the force of the spray, with the result that the skin was not easily wetted. When the nozzle was held at or about 0.5 inch from the skin, it was possible to contact the grub cyst openings directly. This method of application, however, was tedious and wasteful, and it appears that sizable areas of the dorsum might escape coverage by a spray applied in this manner.

Test No. 3 showed that the CS-708 formulation, applied in the form of 1 per cent of the emulsion concentrate (0.25 per cent toxicants), resulted in a grub mortality of only 10.4 per cent. Apparently, this material compares poorly with rotenone in its effectiveness against *Hypoderma* larvae.

Tests 4, 5, 6 and 7 show that the contribution of piperonyl butoxide to the effectiveness against grubs of rotenone is negligible. In addition, the direct action of pyrethrins on the larvae, in the concentration used, was also apparently insignificant. In Test 4, the rotenone content of the formulation was 0.225 per cent, and the grub mortality was 57.2 per cent. A similar formulation containing cube powder alone (Test 7) with a rotenone content of 0.225 per cent, produced a larval mortality of 52.1 per cent. In Test 6, a cube suspension containing 0.45 per cent rotenone yielded a grub mortality of 85 per cent.

These data appear to show that, within broad limits, there is a direct correlation between the rotenone content of the formulations and resulting cattle grub mortalities. These conclusions are in accord with observations on the inclusion of pyrethrins in rotenone formulations, as well as on the use of rotenone activators such as piperonyl butoxide, as determined by Douglas & Furman (1949).

Tests 8 and 9 show that methoxychlor and toxaphene are without promise for the destruction of cattle grubs. Similar results with these two insecticides were reported by Knipling in 1951. In Test 10, ryania also showed a low order of effectiveness against *Hypoderma* larvae.

Tests 11, 12 and 13 were designed to show the value, if any, of the addition of sodium tripolyphosphate to cube washes prepared with and without soap. In all of the three tests, the grub mortalities were relatively high—85.7, 91.9 and 81.6 per cent, respectively. Analysis of variance indicates that the treatment means are not significant at the 5 per

Table 1.—Data on effectiveness of various insecticide formulations against third instar larvae of *Hypoderma bovis*.

Test No.	Insecticide	Animals Treated	Post-Treatment Data		
			Larvae Extracted	Dead Larvae	Per Cent Mortality
1	Aerosol[1]	7	129	33	25.6
2	Aerosol[1]	5	49	16	32.6
3	CS-708	6	67	7	10.4
4	Rotenone-piperonyl[2] butoxide-pyrethrins I	8	215	123	57.2
5	Rotenone-piperonyl[3] butoxide-pyrethrins II	7	150	61	40.7
6	Cube root (5% rotenone) 12 oz. Dreft[4] 1 oz. Water 1 gal.	5	80	68	85.0
7	Cube root (5% rotenone) 6 oz. Dreft 1 oz. Water 1 gal.	6	144	75	52.1
8	Methoxychlor (50% wettable powder) 12.8 oz. Soap powder 2.0 oz. Water 1.0 gal.	5	63	1	1.5
9	Toxaphene (40% wettable powder) 6 oz. Soap powder 2 oz. Water 1.0 gal.	4	55	7	12.7
10	Ryania (100% ground root) 12.8 oz. Soap powder 2.0 oz. Water 1.0 gal.	5	62	5	8.1
11	Cube root (5% rotenone) 6.0 oz. Sodium tripolyphosphate 1.28 oz. Soap powder 2.0 oz. Water 1.0 gal.	5	63	54	85.7
12	Cube root (5% rotenone) 6.0 oz. Sodium tripolyphosphate 1.28 oz. Water 1.0 gal.	5	74	68	91.9
13	Cube root (5% rotenone) 6.0 oz. Soap powder 2.0 oz. Water 1.0 gal.	5	76	62	81.6

[1] Rotenone-piperonyl cyclonene aerosol.

Rotenone	0.3%
Rotenoids	0.45%
Piperonyl cyclonene	1.2 %
Acetone	48.05%
Methyl chloride	50.0 %

[2] Rotenone-piperonyl butoxide-pyrethrins.

Rotenone	2.5%	12 ounces
Pyrethrins	0.5%	
Piperonyl butoxide	10.0%	
Unknown dry diluents and wetting agents	87.0%	
Dreft		1 ounce
Water		1 gallon

[3] Rotenone-piperonyl butoxide-pyrethrins.

Rotenone	2.5%	6.0 ounces
Pyrethrins	0.5%	
Piperonyl butoxide	10.0%	
Unknown dry diluents and wetting agents	87.0%	
Dreft		1.0 ounce
Water		1.0 gallon

[4] Dreft—a proprietary, synthetic detergent containing sodium lauryl sulphate.

cent level of probability. On the basis of these data, it appears that sodium tripolyphosphate contributed little to the effectiveness of rotenone washes. These data also fail to show that this material is superior to soap for the purpose of facilitating the penetration of aqueous suspensions of cube into cattle grub cyst openings. The very small number of animals employed in tests 11, 12 and 13, however, as well as the absence of replications of these tests on additional groups of animals, suggests that further work with sodium tripolyphosphate and related sequestering agents is warranted.

DISCUSSION.—All the materials tested were selected in the expectation that each held some promise for the destruction of grubs. CS-708 was chosen because it was believed to possess insecticidal values in common with rotenone. It is known to be toxic to Mexican bean beetles, *Epilachna varivestis Muls.*, in concentrations approximating those recommended for rotenone and, in addition, is comparatively non-toxic to warm-blooded animals. Methoxychlor was tested for approximately the same reasons. The rotenone-piperonyl butoxide-pyrethrins formulation was reported to be effective against a wide variety of ectoparasites. Ryania was used because of a high order of effectiveness against the European corn borer, *Pyrausta nubilalis* (Hbn.), and the sugar cane borer, *Diatraea caccharalis* (F.). Toxaphene was considered worthy of investigation on the basis of its low chronic toxicity to mammals. Telford (1947) presented evidence that in oil solution and in ointment form toxaphene was relatively ineffective, but it was considered advisable to evaluate its effectiveness in the form of an aqueous suspension. Sodium tripolyphosphate is a sequestering agent with outstanding peptizing and water softening properties. It was used in the hope that by reducing the surface tension of water, it would facilitate the penetration of aqueous suspension of rotenone into partially occluded grub cyst openings.

It is mentioned elsewhere in this paper that all of the materials other than the aerosols were applied in the form of washes. In the opinion of the authors, the wash method of application of insecticides for the destruction of grubs is particulaly well suited for experimental work of this nature. Where insecticides are to be compared from the standpoint of effectiveness, the variables should obviously be confined, as nearly as possible, to the differences which exist between the materials under test. The use of washes permits the application of identical quantities of liquids to each animal, enables the operator to brush each animal with unaltered technique, and in general standardizes the administration of the cattle grub insecticides. It does not always follow that replications of washes produce identical grub mortalities. However, the results obtained showed a high degree of correlation between mortality and the concentration of insecticides applied in this manner. The application of insecticides for grub destruction by means of power spraying equipment, on the other hand, is far better adapted to treating large numbers of animals in a short time than to comparing the effectiveness of various materials. The authors of this paper have frequently demonstrated, in the course of routine grub control practices, the erratic results obtained with high pressure sprays. Differences in third instar mortalities of from 10 to 50 per cent have been encountered in individual members of herds subjected to treatment with the same cube-water sprays, applied by one operator using one piece of equipment. Similarly unpredictable results have been obtained repeatedly between herds in connection with community grub control practices in South Dakota in 1950 and 1951, when operators traveled with their sprayers from farm to farm, administering the same concentration of cube in aqueous suspension time and again. Difficulties of this nature are expressed by Scharff (1950) who urges additional experimental work on the use of sprays.

No controls were included in this series of tests because, during comparable periods, the grub mortality in hundreds of untreated animals was found to be essentially zero.

SUMMARY AND CONCLUSIONS.—Several insecticide formulations were tested for their effectiveness in destroying third instar larvae of *Hypoderma bovis*. Except for a commercially prepared aerosol, the materials were applied to grub-infested cattle, on a comparative basis, in the form of washes. The results were as follows:

1. A rotenone-piperonyl cyclonene aerosol was found to be unsatisfactory for the destruction of cattle grubs; the aerosol bomb method of application appears to be unsuited for grub control.

2. CS-708, two chlorinated hydrocarbon insecticides (methoxychlor and toxaphene), and ryania also were ineffective against cattle grubs, since these materials destroyed only from 1.5 per cent to 12.7 per cent of the third instar larvae in a series of comparative tests.

3. Piperonyl butoxide and pyrethrins, when combined with rotenone, did not appear to contribute to the effectiveness of the rotenone for the destruction of cattle grubs.

4. Sodium tripolyphosphate was not significantly more effective than soap, when used in rotenone washes for the purpose of facilitating the penetration of the insecticide into grub cysts. However, additional tests with this and related sequestering agents appear warranted.

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Effectiveness of Dusts Containing Piperonyl Butoxide and Pyrethrins in Protecting Wheat Against Insects[1]

DONALD A. WILBUR[2]

Kansas wheat growers have long needed a safe and effective insecticide which could be applied to newly harvested wheat as it was being binned, to prevent damage by grain-infesting insects. A newly formulated insecticide containing piperonyl butoxide and pyrethrins impregnated in pulverized wheat known commercially as Pyrenone Wheat Protectant was thought to hold promise in fulfilling this need. The toxicants provided minimum hazards due to their low toxicity to man and animals. (Sarles *et al.* 1949), who would consume the wheat, and the pulverized wheat appeared to be an acceptable vehicle for mixing into the grain mass. From laboratory tests it was found that germination of seed wheat was not affected by treatment, nor was the odor detectable in eggs when treated wheat was fed to laying hens.

During June of 1950 arrangements were made with 32 farmer cooperators in nine Kansas counties to use 73 farm bins to test the effectiveness of the new protectant. Approximately 3820 pounds of the insecticide was made available for use by the farmers and funds were provided for frequent and extensive sampling of the bins and for analysis of the samples. The moisture content of the wheat was so low in many of the bins that insect populations failed to develop in the untreated as well as in the treated bins. The results of the 1950 tests were somewhat favorable to the use of the protectant but not sufficiently so to warrant its recommendation to Kansas farmers. The manufacturers increased the ratio of toxicant to diluent for their 1951 commercial formula.

In June 1951, the company submitted five formulations to the Department of Entomology for testing at the farm bin level. All formulations provided appreci-

[1] Contribution No. 594 Department of Entomology. Studies conducted at the Kansas Agricultural Experiment Station in connection with Commercial Project No. 94 using grant-in-aid funds provided by the U. S. Industrial Chemicals Co.

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able protection but one of these, known as T-460, proved to be outstanding. The following report concerns its effectiveness in preventing insect damage to wheat stored in wooden bins during the first season of storage. This formulation according to U. S. Industrial Chemicals Co. consisted of piperonyl butoxide 1.1 per cent and pyrethrins 0.08 per cent impregnated in pulverized wheat. It was recommended for use at the rate of 75 pounds per 1000 bushels of wheat.

With the help of the county agent, 23 Harvey County farmer cooperators who could provide 63 wooden bins for the 1951 tests were located. The bins were thoroughly cleaned and in most cases the side walls and floors were sprayed with emulsifiable pyrenone spray or DDT spray before harvest time.

APPLICATION OF THE PROTECTANT.—For the most part the protectant was applied to the surface of the wheat in the truck bed at the bin site. Mixing took place during three operations: as the wheat was pushed off the truck into the lifter hopper, again when the wheat was lifted to the bin by the blower, auger, or other lifter, and finally as the wheat and protectant were dropped to the bin and rolled down the cone of the pile. Most of the applications were made by the cooperators who in a few instances modified the method of application to fit their particular circumstances. After the wheat was binned, assistants applied a small additional quantity to the surface of the wheat of each bin. Enough protectant was added and raked into the surface wheat so that the top 3 inches received a double strength application.

In one instance the cooperator misunderstood the directions and layered the protectant in the wheat. But for the most part directions were followed correctly and a thorough mixing of wheat and protectant resulted. When the protectant is properly applied, the ratio of butoxide to wheat is 13.7 parts per million. Samples taken from treated bins and submitted to U. S. Industrial Chemical Company chemists for analysis of butoxide content (Jones 1949) showed this toxicant to be uniformly lower in amount deposited on the wheat than would have been expected from the amount applied.

The protectant increased the amount of dust around the granary.

MOISTURE CONTENT OF THE BINNED WHEAT.—Excessive rainfall during the late spring and early summer of 1951 was unfavorable to high wheat yields. The harvest started at the usual time but rains became so frequent and severe during late June and throughout July that much of the harvest was delayed from 2 to 5 weeks after the grain was ripe. Either the fields were too wet for harvesting machinery or the moisture content of the grain was too high for the grain to be safely binned. As a result, the quality of the wheat was poor and the moisture content abnormally high, frequently too high for safe storage.

The uniformly high moisture content of the 1951 test wheat was of utmost importance to the test, since high moisture in grain is favorable to the development of grain infesting insects and at the same time reduces the effectiveness of the insecticide. In the 1950 and 1951 tests the moisture content of the wheat ranged from 10 to 14.9 per cent. However, in 1951 approximately 97 per cent of the test bins were in the 12 to 15 per cent moisture range and 78 per cent were in the 13 to 15 per cent range. This latter was highly favorable to insect development and thereby provided exceptionally severe conditions for the insecticidal tests. Contrastingly, the 1950 tests were unfavorable for evaluating insecticides as only 19 per cent of the bins were in the 13 to 15 per cent moisture range. In fact 44 per cent of the bins held wheat of from 10 to 11.9 per cent moisture.

SAMPLING OF THE BINS.—There were 5 samplings made during the 1951 season on the following dates: 61 bins Aug. 9–13; 61 bins Sept. 3–4; 48 bins Sept. 21–23; 43 bins Oct. 10–12; and 12 bins Nov. 7–9.

The bin sampling procedure consisted of taking three probe samples of about 450 grams each and a gallon sample. One probe sample was obtained from the center of the bin; the second from a side of the bin approximately one foot from a wall; the third from just under the surface. Each probe sample was retained separately in a moisture-proof glassine sack fitted inside an envelope until it was processed at the laboratory. The gallon sample was taken from various places within the surface foot of the grain and was called the top-foot sample. Top-foot samples were screened on the binsite and

Table 1.—The kinds and numbers of insects originally screened from all probe samples of treated and untreated wheat (*first* screening) and the "hidden infestation" which emerged within the next 35 days (*second* screening).

INSECTS	FIRST SCREENING	SECOND SCREENING
Cadelles	1153	1473
Grain beetles, *Laemophloeus* spp.	940	1254
Saw-toothed grain beetle	180	83
Fungus beetles, unidentified	120	1
Indian meal moth	92	371
Granary weevil	39	135
Beetle, *Palorus ratzeburgi* Wissm.	23	6
Hairy fungus beetle	17	0
Beetles, *Tribolium* spp.	14	6
Rice weevil	9	61
Dermestids, unidentified	2	2
Lesser grain borer	0	27
Angoumois grain moth	0	7
Psocids, unidentified	very many	
Mites, unidentified	very many	

the insects were taken to the laboratory for identification and counting.

TREATMENT OF SAMPLES AT THE LABORATORY.—At the laboratory the moisture content of each sample was determined with a Steinlite electronic moisture tester. Following the moisture determination each sample was given a vigorous *first* screening during which all insects on the outside of the kernels were separated from the grain. The insects were identified as to species or group and the numbers of each determined. The insecticide, grain dust, broken kernels, and other screenings were discarded. The partially cleaned wheat was then placed in quart jars with screened lids and stored in a rearing room of approximately 80° F. and 75 per cent relative humidity for 35 days. On the 35th day the wheat was given a *second* screening, at which time the species and numbers of the insects that constituted a "hidden infestation" at the *first* screening were determined.

INSECTS RECOVERED FROM PROBE SAMPLES.—A total of 2589 insects of at least 18 species, not counting psocids and mites, were secured at the *first* screening and 3431 insects at the *second* screening (Table 1). These insects were obtained from a total of 678 probe samples of 450 grams each taken from untreated bins and bins treated with the five experimental pyrenone formulations.

A significant feature of the above table

Table 2.—Summary of the effects of protective treatment on the numbers of certain grain infesting insects collected at the *first* screening.

INSECTS	PROBE SAMPLES		GALLON-TOP-FOOT SAMPLES	
	Treated	Untreated	Treated	Untreated
Cadelles	50	1027	70	3213
Grain beetles, *Laemophloeus* spp.	146	691	131	2018
Saw-toothed gr. beetle	22	154	3	247
Indian meal moth larvae	32	30	24	57
Granary weevils	23	11	13	9
Rice weevils	4	4	0	0

is the large numbers of insects obtained at the *second* screening. With the exception of those which accidentally failed to be screened out at the *first* screening, these insects were "hidden infestation" at the time of the *first* screening.

Since the insects obtained at the *second* screening were reared after the insecticidal dust had been removed and since their numbers were not reflected in later samplings at the bins, *second* screening insects were not further taken into account in evaluating the effectiveness of treatment.

CADELLES.—A widespread outbreak of cadelles occurred in Harvey County granaries during the summer of 1951. The insects were present in appreciable numbers as adults and small larvae in the August 9 to 13 sampling. The peak of abundance occurred during the September 21 to 23 sampling and light populations persisted in the November 7 to 9 samplings. Small larvae were taken on each of the five samplings, though during the latter part of the season most of the larvae were more than half mature.

A surprising feature of the 1951 samplings was the extent to which cadelles were found among the "hidden infestation" collected at the *second* screening (Table 1). A total of 1279 cadelles averaging 55.6 per bin were taken from samples of untreated bins at the *second* screening. Undoubtedly, some error occurred in the first screening when young cadelles would cling to the wheat kernels and avoid being screened out. However, it is believed that this error was relatively small and that most of the larvae obtained on the *second* screening were buried under the germ coat when the wheat was first screened.

The protectant T-460 was particularly effective in preventing the development of large populations of cadelles, as is evident in table 2. Of the probe samples, 95.4

per cent of the 1077 cadelles collected were taken from untreated bins. Of the gallon top-foot samples, 97.9 per cent of the 3283 cadelles collected were taken from the untreated bins.

Mass migrations of cadelle larvae from heavily populated untreated wheat took place during the September 21 to 23 sampling. Interior and exterior walls of the bins, under surface of the roof above the untreated bins, and the concrete drive-in were covered with the fully developed larvae which were either moving away from the bins or attempting to burrow into the woodwork. It is remarkable that following such migrations more larvae were not collected from nearby treated bins.

GRAIN BEETLES, *Laemophloeus* spp.—Grain beetles of the genus *Laemophloeus* were the second most abundant of the grain-infesting insects secured at the *first* screening. Schwitzgebel and Walkden (1944) working in Reno County, which adjoins Harvey County on the west, found these insects in flight about farm bins throughout the summer. These beetles were already in the bins at the time of the August 9 to 13 sampling and had increased to population peaks by the September 21 to 23 and the October 10 to 12 samplings. Grain beetles were found in nearly all the bins sampled but they were much more abundant in the untreated bins. Twenty-three per cent of the probe samples from untreated wheat would grade weevily on the grain beetle count alone as compared with seven per cent for treated wheat.

Grain beetles, as well as cadelles, appeared in significantly large numbers in the *second* screenings (Table 1), indicating that these insects are likely to constitute an important hidden infestation problem, particularly during the early months of the storage period.

Grain beetles are active migrants around the granaries and feed rooms during the summer and fall months. Treated bins with sizable populations of grain beetles were all in granaries in which the untreated bins had overwhelming populations. It seems safe to assume that the grain beetles collected from treated bins would have been appreciably fewer had all bins in the granary been treated.

Grain beetles were not identified to species in this study, but both flat grain beetles, *Laemophloeus minutus*, and red grain beetles, *L. ferrugineus*, were known to have been present.

SAWTOOTHED GRAIN BEETLES.—Sawtoothed grain beetles were the third most abundant of the insect species collected at the *first* screening, and an appreciable number was collected at the *second* screening. Double treatment of the surface grain practically eliminated them from the top-foot region of the bin, but a few more were located deeper in the grain by the probe sampling. The presence of sawtoothed grain beetles in the bins under test was spotty. They were collected in considerable numbers in a few of the untreated bins.

INDIAN MEAL MOTH LARVAE.—Larvae of Indian meal moths were observed in limited numbers in approximately half of the treated and half of the untreated bins under observation, though damage was light in all cases. The larvae appeared to be unaffected by treatment with the protectant.

GRANARY WEEVILS, RICE WEEVILS, AND LESSER GRAIN BORERS.—The numbers of weevils and lesser grain borers collected at the samplings were too low and too scattered from both treated and untreated bins to be of value in determining the effectiveness of the protectant. These insects were certainly not a factor in the deterioration of the wheat in the bins under test during the first season of storage. None of the species appeared in the probe samples until the September 21 to 23 samplings.

SURVEY OF EXPERIMENTAL CONDITIONS AND RESULTS OF THE PROTECTANT TREATMENT IN SELECTED GRANARIES.—Each farm granary is a problem in itself in so far as grain-infesting insects are concerned. The sources of such insects with which each succeeding crop is infested are likely to be peculiar to a particular farm. That is why it is considered essential to evaluate results strictly on a farm granary basis, and why results obtained in different farm granaries are so difficult to interpret.

The following case histories of farm granaries deal with the more abundant and significant insect species and numbers collected from the bins under test. The treated and untreated bins in these farm granaries have had as near an equal opportunity for uniform initial infestation

as can be expected from farm tests. The granaries discussed in detail in this report were selected because of the appreciable insect populations which developed in the untreated bins. Granaries in which insect populations failed to develop in untreated bins were not useful in evaluating the effectiveness of treatment.

The more important variables that can be expected to occur among the various bins in the farm granary unit are:

1. Moisture content of the various lots of wheat.
2. Sanitation of the bins and of the area around the bins.
3. Availability of grain-infesting insects.
4. Distance from source of grain-infesting insects.
5. Structure of the bins.
6. Thoroughness and uniformity in the application of the protectant.

J.M.D. Granary.—The test bins were situated at opposite ends of a boxcar adapted for grain storage. The treated and untreated bins were separated by a thin wooden partition. They were well constructed and the sanitation within and around them was excellent. Spraying was done before the new crop was harvested. The wheat was of a uniform moisture content in the 13 to 13.9 per cent group.

RESULTS.—Protection afforded by treatment—outstanding.

G.R. Granary.—The test bins were located within a small well-constructed wooden granary which stored corn and oats as well as wheat. Sanitation was fair. The bins were sprayed before harvest. The moisture content of the treated wheat was in the 14 to 14.9 group, and of the untreated wheat, 13 to 13.9.

Results.—Protection afforded by treatment—outstanding, though the population in the untreated bin was relatively low.

C.D. Granary.—The test bins were located within a clean, well-constructed farm elevator. A quantity of oats, wheat, and corn was stored in the elevator in addition to the test wheat. Test bins were sprayed before the harvest. The moisture content was uniformly high, between 13.7 and 15.0 per cent. After the first sampling another bin of wheat was substituted for the untreated bin which early went out of condition from high moisture heating. During the period of the test, the bins were turned by the grainlifting machinery to help condition the wheat.

Results.—Protection afforded by treatment—outstanding.

J.V. Granary.—The test bins were located in two separate buildings about 150 feeet apart. The treated bin was in a two-bin granary and the untreated bin was by itself. The sanitation was poor but the bins were sprayed. The treated bin had a moisture range of 12.5 to 13.5 and the untreated bin had a range of 13.5 to 14.5.

Results.—Protection afforded by treatment—outstanding.

W.D. Granary.—The test bins were located side by side in a large fairly well-constructed granary. Two other bins were contracted for treatment but the wheat was so moist that it could not be stored. The bins were unsprayed and the sanitation was only fair. The moisture content of the wheat in the treated bin ranged between 12.5 and 14.0, while that in the untreated bin was from 14.0 to 14.9.

Results.—Protection afforded by treatment—outstanding.

F.D. Granary.—The test bins were located in a livestock and hay barn. The sanitation was poor but the bins were sprayed. The moisture content of the treated bin was between 12.5 and 13.5, while in the untreated bin it was between 13.5 and 14.5.

Results.—Protection afforded by treatment—outstanding.

J.N. Granary.—The test bins were all located in a well-constructed wooden granary. The sanitation was fair and all bins were sprayed. The moisture content in the untreated bin was between 12.0 and 13.5, while in the treated bin it was between 13.0 and 14.5.

Results.—Protection afforded by treatment—outstanding.

H.H. Granary.—The test bins were located at opposite ends of an old boxcar granary which had a history for infested grain. The treated end of the car was sprayed but the untreated end was left unsprayed. Sanitation was poor. The moisture content of the wheat in the treated bin ranged between 13.5 and 15.0, while that of the untreated bin was between 12.7 and 13.8 per cent.

Results.—Protection afforded by treat-

Table 3.—Total cadelles (cad.) *Laemophloeus* spp. (Laem.), and saw-toothed grain beetles (Swtd.) collected from 10 Harvey County granaries from bins of treated and untreated wheat by probe and gallon top-foot samples.

Granary	Probe Samples						Gallon Top-Foot Samples					
	Treated			Untreated			Treated			Untreated		
	Cad.	Laem.	Swtd.	Cad.	Laem.	Swtd.	Cad.	Laem.	Swtd.	Cad.	Laem.	Swtd.
JMD	1	2	0	128	19	0	1	0	0	448	35	0
GR	0	0	0	20	7	0	0	0	0	32	2	0
CD	2 6	5 58	2 0	33	104	2	0 0	0 0	0 0	535	258	0
JV	1	0	0	9	9	99	2	0	0	2	75	227
WD	9	1	0	189	43	0	1	0	0	239	49	3
FD	2	1	0	53	1	2	2	0	0	184	4	0
JN	10	2	0	110	20	0	0	1	0	216	6	0
HH	9	42	0	71	191	0	16	76	0	264	244	0
RH	0	8	14	93 105	90 126	18 1	15	1	0	433 378	303 945	12 0
GG	1	3	0	61	31	6	2	0	0	185	19	0
Total	41	122	16	880	641	128	39	78	0	2916	1940	242
	Chi-square equals 62.6, 2 degrees of freedom, P much less than .001.						Chi-square equals 41.2, 2 degrees of freedom, P much less than .001.					

Note: Granary C. D. has 2 treated bins; R. H. has 2 untreated bins.

ment—good but not outstanding; the poorest control of any of the bins in the test.

R.H. Granary.—The test bins were located in a well-constructed wooden granary with pits under the bins on either side to provide ventilation. Sanitation was excellent except for accumulations of grain in the pits. Samples from this accumulation of grain revealed several species of grain-infesting insects. The bins were unsprayed. The moisture content of bins was relatively uniform, between 13.5 and 15.0 per cent.

Results.—Protection afforded by treatment—outstanding.

G.G. Granary.—Test bins were located in a well-constructed wooden granary. Sanitation was good; bins were unsprayed. The moisture content of the treated bin was between 14.0 and 14.8; the untreated bin was between 12.8 and 13.9.

Results.—Protection afforded by treatment—outstanding.

Extent of Probe Samples Grading Weevily.—Each of the 504 probe samples taken during the tests was graded to determine the extent of its weevily condition according to U. S. grain grading standards. According to these standards wheat is graded weevily if a 1000-gram quantity contains two weevils, or five bran beetles, or one weevil and three bran beetles. Since the probe samples weighed 450 grams, it was necessary to multiply the figures representing insect populations by the factor 2.2 to convert the sample to 1000 grams.

Of the 243 probe samples from 21 bins of treated wheat, 14.8 per cent were graded weevily. Of 261 probe samples of untreated wheat, 61.6 per cent were graded weevily. It seems likely that the percentage of treated wheat graded weevily would have been appreciably less had the treated wheat not been in such close proximity to the untreated wheat. This situation afforded opportunity for a continuous migration of the exceptionally large insect populations in the untreated wheat to adjoining areas.

In table 4, the data from all treatments are organized to show the effects of the time of sampling. The increasing number of samples grading weevily as the storage season progressed is clearly evident in both treated and untreated probe samples. The data for the November 7 to 9 sampling are not strictly representative because only those bins were sampled which had excessive populations in the untreated bins.

Insect-Damaged Kernels in Treated and in Untreated Bins.—An effort was made to determine the extent to which numbers of grain-infesting

Table 4.—Weevily wheat grades in wheat treated with five experimental dust formulas and in untreated wheat at the different sampling dates.

Sampling Date	Treated			Untreated		
	Bins	Probe Samples	Graded Weevily	Bins	Probe Samples	Graded Weevily
Aug. 9–13	37	111	2.7%	24	72	50.0%
Sept. 3–4	37	111	15.3	24	72	56.9
Sept. 21–23	30	90	20.0	18	54	74.7
Oct. 10–12	28	84	26.2	15	45	62.2
Nov. 7–9	7	21	38.1	5	15	93.3

insects collected from the various treated and untreated bins, and the grading of all probe samples according to the U. S. Grain Grading Standards, was reflected in the amount of damage to the kernels themselves. Two half-gallon samples of wheat were taken by grain probes from various parts of 18 bins from seven farm granary units during the November 7 to 9 sampling. Only those granary units were selected in which the populations in the untreated bins were large. After each sample was thoroughly mixed, three 1000 kernel lots were selected at random for examination. During the examination which was made under a lens and verified under a binocular microscope, all kernels showing evidence of insect damage, great or small, were separated and counted.

An appreciable number of kernels appeared undamaged to the naked eye but with the aid of the microscope a small entrance to the germ of the kernel could be seen. When the coating of the germ was removed, varying amounts of the germ were found to have been consumed.

The data in table 5 are averages of the three 1000-kernel samples and indicate the high degree of effectiveness of the insecticidal dust in protecting the wheat kernels from insect damage:

Table 5.—The effectiveness of protectant dusts containing piperonyl butoxide and pyrethrins in preventing insect damage to wheat kernels.

Bin Number	Treated	Average Number of Kernels per 1000		Per Cent of Damaged Kernels
		Damaged	Undamaged	
1T	Yes	5	995	0.5
2C	No	99	901	11.0
8T	Yes	1	999	0.1
9T	Yes	0	1000	0.0
7C	No	49	951	5.2
20T	Yes	3	997	0.3
21T	No	114	886	12.0
37T	Yes	4	996	0.4
36C	No	39	961	4.1
47T	Yes	32	968	3.3
48C	No	132	868	15.2
58T	Yes	11	989	1.1
60C	No	75	925	8.1
67T	Yes	5	995	0.5
68C	No	75	925	8.1

SUMMARY.—Tests with insecticidal dust protectants consisting of piperonyl butoxide and pyrethrins impregnated in pulverized wheat were made on Kansas farms following the harvests of 1950 and 1951. These protectants were applied to wheat in the truck beds. Mixing occurred during the binning process.

The 1950 treatments resulted in lower populations of grain-infesting insects during the first storage season but not enough decrease to warrant recommendation to Kansas wheat growers to use the treatment.

The 1951 harvest was delayed appreciably by rains, which resulted in low quality and high moisture content in the harvested wheat. High moisture content in wheat not only is favorable to the development of large populations of grain-infesting insects, but also reduces the effectiveness of the insecticidal treatment.

The treated and untreated bins were sampled by probing with an ordinary grain trier in the top, side, and center of each bin at each sampling date. On the 2nd, 3rd, and 4th sampling dates, one-gallon samples were taken at random from the top-foot of each bin. The sampling started August 9 to 13 and continued at regular intervals until November 7 to 9, making a total of five samplings.

When the samples reached the laboratory, they were tested for moisture, screened for insects, and placed in a rearing room for 35 days. On the 35th day they were screened again for reared insects, which represented "hidden infestation" at the *first* screening.

A total of 2589 insects, not including mites and psocids, were obtained at the *first* screening of the probe samples. On the *second* screening, 3431 insects were secured. At least 19 species of insects were taken, of which the cadelle, grain beetles, and sawtoothed grain beetles were present in the larger numbers. With one exception,

rice and granary weevils were not a significant factor in the bin infestations in the 1951 crop.

The effectiveness of the treatments was determined by comparing insect populations in treated and in untreated bins within a single granary where equal opportunities for infestation were available. This report presents data from 10 granaries in which the untreated bins developed appreciable insect populations. The Chi-square test applied to data in table 3 indicated that treatment most decidedly has changed the proportions of the three insectan species, cadelles, *Laemopholeus* spp., and sawtoothed grain beetles.

The pyrenone protectant, formula T-460, showed outstanding protectant value when applied to newly-harvested wheat of high moisture content and held in storage in farm bins of wooden construction. The other experimental pyrenone formulas likewise showed varying degrees of protectant values.

All probe samples were graded according to U. S. Grain Grading Standards to determine the extent of weevily wheat. Wheat treated with protectant T-460 average 14.8 per cent weevily grade as compared to 61.6 per cent for untreated wheat. The later the sampling date, the higher the percentage of wheat grading weevily.

Three thousand kernels of wheat selected at random from bins in granaries with well-established insect populations in the untreated bins were examined under a microscope to determine the difference in amount of damage in treated and in untreated bins. Appreciably higher kernel damage was found in untreated than in treated wheat.

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Reactions of Oriental Fruit Fly to High Temperatures and Various Relative Humidities

C. C. ROAN, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*

In the summer of 1950 a series of laboratory studies were initiated to investigate the reactions of the oriental fruit fly, *Dacus dorsalis* Hendel, to carefully controlled environmental factors. The results of an investigation of the reactions of the adult fruit fly to high temperatures and various relative humidities are presented in this paper.

TEMPERATURE PREFERENCE.—The temperature preference of this insect provided a logical starting point for these studies. The apparatus employed for this phase of the investigation consisted of a temperature-gradient bar based on the method used by Martini (1918). This bar was made of cast aluminum with outside dimensions of 35 by 2.25 by 1.125 inches. The dimensions of the test area inside the bar were 32.5 by 1.5 by 0.5 inches. The top of the bar was covered with a strip of quarter inch plastic. Eight holes were unformly spaced along one side to permit the insertion of thermometers. An aluminum rod 2 by 4 inches was bolted to each end of the bar at right angles to its longitudinal axis. These rods were inserted into constant-temperature water baths of appropriate temperatures to produce a gradient of temperatures along the floor of the bar, which were measured by means of the thermometers inserted along the side of the bar. The high temperatures were produced in a water bath equipped with an electric stirrer, and an electric immersion heater controlled by a mercury thermoregulator and an electronic relay. The other end of the bar was cooled in an ice-salt mixture.

For each test 50 female flies selected from a laboratory culture were placed in the apparatus while it was at room tem-

perature. These flies had not undergone any previous conditioning other than exposure to prevailing laboratory conditions. No attempt was made to control the relative humidity of the test area. After the distribution of the flies had become fairly uniform, one end of the bar was gradually heated while the opposite end was cooled. Three observation points were selected, at each end of the bar and at the center. The temperatures and per cent of flies present at the different positions (Nos. 1, 2, and 3) were determined at 10-minute intervals, as shown in table 1 and figure 1, respectively. These data represent the averages of the experiments and have not been subjected to a statistical analysis since only qualitative results were desired.

Table 1.—Temperatures (° C.) at three positions in the gradient bar at 10-minute intervals after it was heated. Temperature of unheated bar 29° C.

	After Minutes Indicated				
Position	10	20	30	40	50
1	36	45	47	47	47
2	29	29	30	30	30
3	22	19	20	19	19

The distribution of flies throughout the bar after the gradient was established is shown in figure 2. These data were obtained from the previous experiments after the gradient had become relatively constant.

The flies in the hot end of the bar were very active, with a considerable amount of movement in and out of the warmer regions, but at the cold end of the bar, they did not attempt to move about. Since considerable difficulty was experienced in producing low temperatures, it is difficult to predict at this time how far these insects will move into a progressively cooler region of the bar before being stopped by a cold rigor.

The data from the preceding experiments indicate the upper limit of the temperature preference may be in the region of 37° C. To explore this reaction in greater detail a modification of the gradient bar was used. This consisted of a U-shaped copper trough 3 by 0.5 by 0.75 inch covered with a strip of quarter-inch plastic. Three thermometers were inserted through equally spaced holes in the plastic cover.

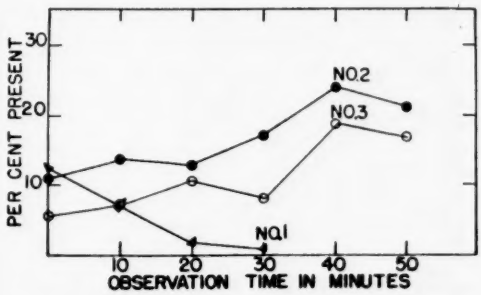

FIG. 1.—Reactions of female oriental fruit flies to changing conditions at three positions in a temperature-gradient bar.

A temperature gradient of the order previously determined as acceptable to the flies was established. Ten flies selected at random from a laboratory culture were placed in the apparatus for each test. Three readings were taken at each increment in the changing gradient before a new gradient was established. The results of this experiment, which was repeated three times, are presented in figure 2. As will be seen from these data, one end of the apparatus was heated slowly while the opposite end was cooled sufficiently to maintain a temperature never exceeding the temperature of the middle region at the onset of the experiment. These data show more clearly the tendencies of the fruit flies to avoid temperatures above 35° C.

HEAT RIGOR AND KNOCKDOWN TIME.—In the preceding experiments flies entering the region above 41° C. became prostrate after a very short time. This observation led to an investigation of the length of exposure to various temperatures nec-

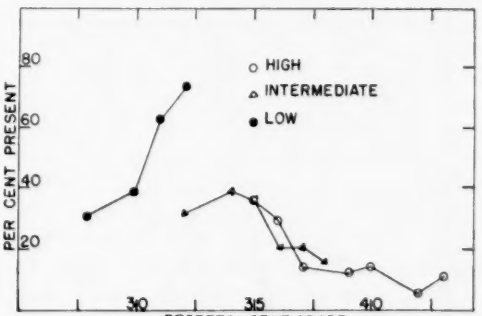

FIG. 2.—Upper limit of the temperature preference of adult oriental fruit flies determined by a progressively changing temperature gradient. The first point plotted on the left of each line represents the initial fly distribution.

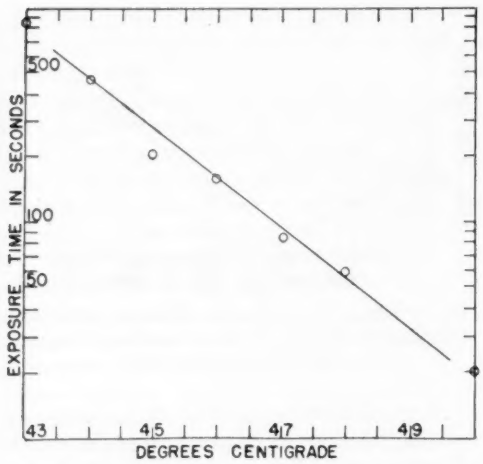

FIG. 3.—Time of exposure to various temperatures required to produce 100 per cent knockdown of oriental fruit flies from heat rigor.

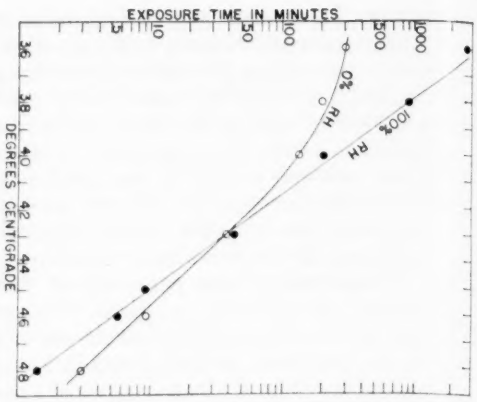

FIG. 5.—Exposure periods producing 50 per cent mortalities of oriental fruit flies at various temperatures and two extremes of relative humidity.

essary to produce a knockdown from heat rigor. In these experiments 125-ml. Florence flasks were used as test chambers. These flasks were placed in a water bath so that the water came up over half way on the neck of the flasks. Initially the neck of the flask was closed with a cork stopper with a mercury thermometer inserted through the stopper so that the bulb extended into the center of the flask. When the air temperature in the flask had reached the desired level, the test flies were introduced and the time for 100 per cent knockdown was recorded.

Ten test flies were selected at random from a laboratory culture of known age. These flies were aspirated into a pickup tube consisting of a 4-inch length of glass tubing with an outside diameter just small enough to permit its insertion through the neck of the test flask down into the center of the flask. The end of the pickup tube that was attached to the vacuum line was drawn down slightly and plugged with a wad of cotton. After the flies were in the tube the opposite end was closed with another cotton plug. The tube was inserted into the center of the test flask and the flies and cotton plugs driven out of the tube by a glass rod inserted through the small end. After the tube was withdrawn the neck of the test flask was closed with a cotton plug extending below the water level, so that the only area of the

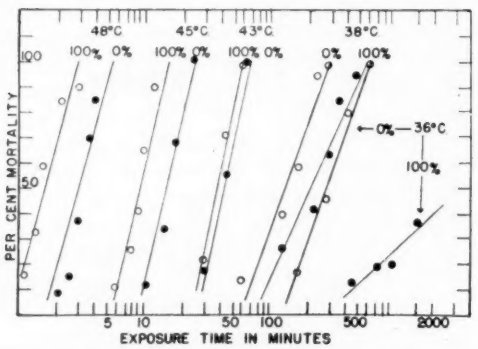

FIG. 4.—Lethal effects on oriental fruit flies of various exposure periods to temperatures ranging from 48° to 36° C. under conditions of the extremes of relative humidity.

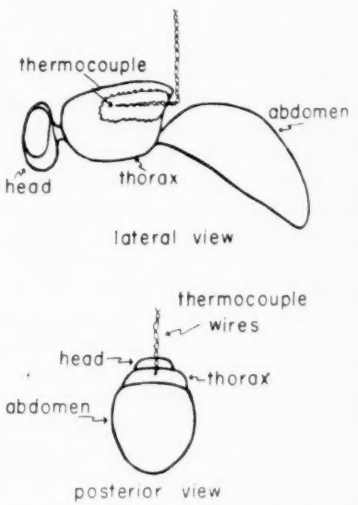

FIG. 6.—Diagram showing the point of insertion of the thermocouple into the thorax of an oriental fruit fly and the relative positions of the fly and the lead wires.

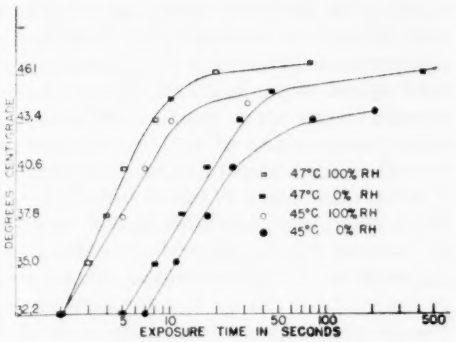

FIG. 7.—Changes in body temperature of oriental fruit flies as indicated by thermocouples, when placed in a 4 by 4 by 3¼ inch plastic test chamber having the indicated temperatures and relative humidities.

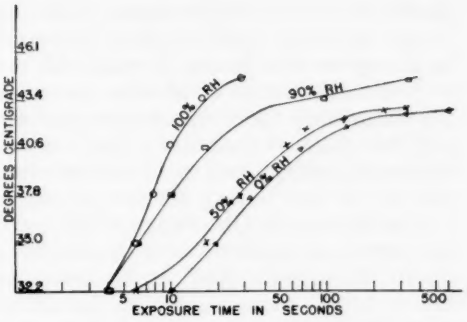

FIG. 8.—Changes in body temperature of oriental fruit flies, as indicated by thermocouples, when placed in a 125-ml. Florence flask at 45° C. with the relative humidities indicated.

flask accessible to the flies was below the level of the water bath.

Repeated tests with this method of introducing the flies into the test chamber indicated no discernible damage to the flies. Neither was there any detectable change in the air temperature of the test flask. The data in figure 4 represent the average of 10 tests at each temperature level. At the lower temperatures there was considerable variation in the knockdown times; nevertheless, the averages represent adequately the relative differences in the effects of the various temperatures.

LETHAL EFFECTS OF HIGH TEMPERATURES.—In order to investigate the thermal death point for *Dacus dorsalis* adults, the subject was approached from a broad aspect. Rather than establish an arbitrary exposure period for determining the thermal death point, a range of temperatures and exposure periods were investigated. Since Beattie (1928), Mellanby (1932), and Gunn & Notley (1936) had reported the effects of relative humidity on the thermal death point of various insects, the effects of the two extremes of relative humidity were investigated at the same time.

These experiments were performed in the same manner as those described for heat rigor with the following additions. At the end of the exposure period the test flasks were removed from the water bath and the flies rapidly transferred to recovery cages. Half-pint, wide-mouth, mason jars covered with cheese cloth were used as recovery cages. The flies were provided with sugar and water during the recovery period. Mortalities were determined at the end of 24 hours.

Temperatures ranging from 48° to 36° C. were investigated. At each temperature level two extremes of relative humidity were employed, 100 and 0 per cent. A condition approaching saturation (100 per cent) was obtained by placing small pieces of sponge saturated with water and enclosed in fine-mesh screen-wire cylinders in the bottom of the flask. Calcium chloride in the same type of cylinders was used to obtain the opposite condition.

Fifty flies selected at random from a laboratory culture were used for each test. Duplicates of each condition and exposure period were run for each test and the tests were replicated at least three times. For convenience only five temperature levels are shown in figure 5. Additional tests at 46°, 44°, and 40° C. resulted in data intermediate between the values actually reported here.

The exposure periods necessary to produce 50 per cent mortalities at the various conditions of temperature and humidity are plotted in figure 5. At temperatures above 43° C. (Figs. 4 and 5) a low humidity favors survivals under the conditions of these experiments, whereas below 43° low humidities are inimical to the fly. These data suggest that at low humidities this fly can maintain for a short period a body temperature slightly lower than the environmental temperature. This may be accomplished by water evaporating from the insect as suggested by Mellanby (1932). At temperatures above 43° the relatively short exposure periods would not result in sufficient water loss to be hazardous to survival. On the other

hand, at lower temperatures with the longer exposure periods, water loss could be a very serious factor. It might be well to point out that at conditions approaching saturation there was ample opportunity for the flies to obtain water, whereas at zero humidity there was no water available to the flies during the test period.

The change in the shape of the curve for zero per cent relative humidity in figure 6 suggests that at temperatures below 43° C. desiccation may be an important factor in the survival of the flies.

BODY TEMPERATURES AT HIGH ENVIRONMENTAL TEMPERATURES.—Since the data from the experiments on the thermal death point suggested the possibility of adult fruit flies maintaining, at low relative humidities, a body temperature lower than their environmental temperature, an attempt was made to measure the body temperature of this insect.

Microthermocouples were fabricated from No. 40 B&S gauge copper and constantan wires. Such thermocouples could easily be inserted into the thorax of an adult fly, but were strong enough to withstand considerable manipulation. These thermocouples were used in conjunction with a potentiometer calibrated to indicate temperature in degrees Fahrenheit and equipped with an automatic reference junction compensator. The thermocouples were checked against common laboratory thermometers, and were found to agree at the points tested, *i.e.*, 0°, 20°, and 45° C. The thermocouple was inserted in the thorax (Figure 6) since it is more rigid and tolerant of manipulation. The thorax also has a rich, heavy musculature which could protect essential organs from damage by the thermocouple.

When the thermocouple was inserted, the fly could assume a normal attitude and make free use of its appendages. Flies suspended in this manner frequently attempted to fly when support was removed from their legs. Superficial examinations revealed no damage from the insertion of the thermocouple. Flies that had not been subjected to particularly adverse conditions *i.e.*, long exposures to high temperatures, etc., were frequently observed to walk or fly away upon removal of the thermocouple.

In the initial experiments a clear plastic box 4 by 4 by 3.25 inches was mounted in the constant-temperature bath. Holes were cut in the lid for insertion of a laboratory stirrer, a thermometer, and a cork stopper through which the thermocouple lead wires were inserted. Two thermocouples were used, one to indicate the body temperature of the test fly and the the other the environmental temperature.

After the desired environmental conditions had been established, a fly selected at random from a laboratory culture was impaled on a thermocouple. Since in the process of handling the temperature of the fly approached that of the operator's fingers, the fly was then allowed to remain suspended in the laboratory until its temperature approached that indicated by the adjacent bare thermocouple. The fly and the adjacent thermocouple were then inserted into the test chamber and the rate of body temperature increase determined. Control experiments with bare thermocouples indicated that they reach environmental conditions within 5 seconds. The results of a series of experiments at 47° and 45° C. with 100 and 0 per cent relative humidity are shown in figure 8. Ten flies were used for each condition of temperature and humidity. These data indicate that under conditions approaching 0 per cent relative humidity these flies maintain a body temperature appreciably lower than the environmental conditions.

To compare these data with those from the experiments on the lethal effects of high temperature, another series of experiments were performed employing 125-ml. florence flasks as test chambers. The humidity control was placed in the bottom of the flask and the flies were sus-

Table 2.—Body temperature (° C.) of oriental fruit flies subjected to gradually rising temperatures at 100 and 0 per cent relative humidity.

TIME (Minutes)	100 PER CENT RELATIVE HUMIDITY		0 PER CENT RELATIVE HUMIDITY	
	Fly	Flask	Fly	Flask
0	25.0	25.0	25.0	25.0
4	27.2	27.2	25.6	27.2
8	30.0	30.0	28.9	30.0
12	33.3	33.3	32.2	33.3
16	36.7	36.7	35.6	36.7
20	40.0	40.0	38.9	40.0
24	42.8	42.8	41.1	42.8
28	46.1	46.1	43.9	46.1
32	46.1	46.1	44.5	46.1
34	46.1	46.1	44.5	46.1

pended in the center of the flask by thermocouples. Two intermediate humidities, 90 and 50 per cent relative humidity, were incorporated in these tests. The results of these experiments are shown in figure 8.

Figures 7 and 8 show that at low humidities the body temperature of the fly approaches that of its environment much more slowly under dry conditions than under conditions approaching saturation. However, at saturation the latent heat of condensation could materially affect the rate of change of body temperature. To investigate the degree to which the latent heat of condensation might affect the body temperature, an experiment was carried out under conditions which should minimize this effect.

The flies were placed in the test flasks while the flasks were at room temperature. The flasks were then placed in a temperature bath and gradually heated. The temperatures of the flies and the test flasks were observed and recorded at 4-minute intervals. These data in table 2 show that the latent heat of condensation is not entirely responsible for the differences in body temperatures at 100 and 0 per cent relative humidity.

CONCLUSIONS.—The data presented in this paper indicate that:

1. The upper limit of the temperature preference of adult *Dacus dorsalis* flies falls in the region of 35° C. Determination of the lower limit is complicated by a tendency for these flies to become "cold trapped."

2. The exposure time necessary to produce 100 per cent knockdown from heat rigor ranges from 20 seconds at 50° to 15 minutes at 43° C.

3. At temperatures above 43° C., with short exposure periods, dry conditions favor survival, whereas at lower temperatures and longer exposure periods dry conditions appear inimical to survival. These differences may be attributable to cooling by water loss at the higher temperatures.

4. Thermocouple measurements indicate a body temperature lower than environmental temperatures at low humidities, whereas at high humidities the body temperature rapidly approaches environmental conditions.

5. The more rapid rate of increase of body temperatures at high humidities is not completely attributable to latent heat of condensation.

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K. P. EWING IN NEW POSITION

Mr. K. P. Ewing, research entomologist with the Cotton Insect Division of the B.E.P.Q. for 32 years has been selected to coordinate the expanded cooperative research programs of the Bureau and other agencies set up to bring the pink bollworm under control. Mr. Ewing's task will be the organization of of the various agencies set up to fight the pink bollworm and the administration of cotton insect surveys and research in Texas and Oklahoma.

DR. EDWARD W. BAKER

For some years the Washington Academy of Sciences has made three awards annually to young scientists in recognition of outstanding achievement, one each in the engineering sciences, the physical sciences and the biological sciences. Candidates must be members of the Academy or of one of the 19 affiliated societies and must not be more than 40 years of age. This year the award in the field of the biological sciences was given to Dr. Edward W. Baker, mite specialist in the Division of Insect Detection and Identification of the Bureau of Entomology and Plant Quarantine in recognition of his distinguished research on the classification of the mites.

Control of the Northern Fowl Mite

DEANE P. FURMAN,[1] *University of California, Berkeley*

Control of most poultry ectoparasites is relatively easy to accomplish with currently recommended procedures. An exception to this generalization is represented by the northern fowl mite, *Bdellonyssus* (=*Liponyssus*) *sylviarum* (Can. *et* Fanz.). Serious infestations of this mite occur frequently on California poultry. The poultry industry has long recognized that such infestations are accompanied by rapid loss of condition of birds and decreased egg production. In addition to playing a significant role as a poultry pest, the northern fowl mite must now be considered as a potential reservoir, and/or vector of the virus causing western equine encephalomyelitis, since it has been found naturally infected with this virus, Reeves *et al.*, 1947.

Strangely enough, in view of the rapidity with which colonies of this mite build up in nature, difficulties have been experienced in maintaining the species in the laboratory. Chamberlain & Sikes (1950) have recently described a satisfactory laboratory rearing method.

The early literature on biology and control of *Bdellonyssus sylviarum* has been reviewed by Cameron (1938). The materials and methods described by Cameron and by subsequent workers (Peterson 1949, Ritcher & Insko 1948, Povar 1946) are in part fairly effective in controlling mites, but none of them meets the requirements established for a good poultry "insecticide," namely: effective control, simple and rapid applicability, residual control effect, absence of tainting qualities, low toxic hazard, and low cost.

Nicotine sulphate is frequently recommended for control of *Bdellonyssus sylviarum*. By the drop method of application applied individually to birds, effective control is obtained. The treatment is hazardous to young birds and occasionally to adult poultry. When used as a roost paint as described by Payne (1929) the results are uncertain; frequently control is poor. This method is, of course, impractical for use with caged birds on wire.

Widely recommended at present is a dip composed of 2 ounces of flowers of sulphur and 1 ounce of soap per gallon of water. This formulation, properly employed, is effective in controlling most infestations of *Bdellonyssus sylviarum*. It has the disadvantage that the birds must be handled individually and be thoroughly wetted. The method is thus impractical for use with most large flocks and then only on warm days.

Povar (1946) reported that DDT was effective in killing *Bdellonyssus sylviarum* in tests where the mites were exposed to the material in petri dishes. On birds dusted with 10 per cent DDT, however, the mites were not controlled. He found that sulphur was ineffective when tested by the petri dish method.

Ritcher & Insko (1948) evaluated the control of *Bdellonyssus sylviarum* resulting from application of several different materials applied as dusts using 8 pinches of dust per bird placed back of the head, under the wings and near the vent.

They reported only very temporary reduction of infestations following treatment with any of the following: (1) sodium fluoride powder; (2) 10 per cent beta beta dithiocyano diethyl ether;[2] (3) 5 per cent DDT; (4) 0.5 per cent gamma isomer benzene hexachloride (applied as 5 per cent technical BHC); (5) 10 per cent sabadilla.

Beta beta dithiocyano diethyl ether was reported by Peterson (1949) to blister birds when applied as a 1–9 dilution in water. As a 7.5 per cent dust, however, he stated it produced fair control of *Bdellonyssus sylviarum* with no indication of blistering. Using a benzene hexachloride suspension containing 0.25 per cent of the gamma isomer, applied to the vent of birds, control of the mites was not obtained.

The purpose of the present report is to evaluate several materials which appear to be promising on the basis of their effectiveness against zoöphagous or phytophagous mites. Several of these in commercial formulations are already available, are relatively inexpensive, and seem to have a very low degree of toxicity for warm-blooded animals. It also appears

[1] The author acknowledges with appreciation the assistance of Mr. G. H. Rohrbacher, and the cooperation of Mr. W. S. Coates and Mr. J. W. Melendy, Farm Advisors in Alameda and Santa Cruz Counties, respectively.

[2] *Lethane A-70* (a Rohm and Haas product containing 90 per cent by weight.

desirable to evaluate the relative effectiveness of representative chlorinated hydrocarbon insecticides and other formulations concerning which conflicting reports appear in the literature.

METHODS AND MATERIALS.—With minor modifications the method of Chamberlain & Sikes (1950) was used in rearing laboratory colonies of *Bdellonyssus sylviarum*.

Screening tests to determine the effectiveness of formulations against active stages of the mites were conducted as follows: A circle 2 inches in diameter was inscribed in the middle of a petri dish with a glass-wax marking pencil. The dish was then exposed for 2 seconds to an air-dust blast from a small laboratory power-duster. This was sufficient to provide a layer of dust several particles deep on the glass surface. Water was added outside the inscribed circle to provide a moat. One hundred or more mites were placed in the treated circle by means of a pasteur pipette and the dish was then covered to maintain a high relative humidity. These screening tests were conducted at laboratory temperatures ranging from 60 to 80° F. Controls were set up as indicated in table 1.

Formulations were also screened for toxicity to eggs and active stages of mites and for toxicity to birds in the laboratory by dusting 1 to 2-day-old chicks for 10 seconds each, using a small laboratory power duster. Following treatment the chicks were infested with 1000 or more mites each and held in individual battery jars surrounded by a water moat. The temperature was held at 85° F. ±2 degrees and the relative humidity at 75 to 85 per cent. Each jar was furnished with water and feed containers and litter of excelsior. Controls were conducted for each check.

On the basis of the laboratory screening tests the more promising materials were tested in field experiments on adult chickens. Three types of dusting treatments were employed. As the name implies the pinch method consists of applying a pinch of dust, taken between the thumb and forefinger, to the feathers of the bird. As used here 8 pinches were applied per bird, one each to the back of the head, back of neck, back between wings, under each wing, middle of breast and above and below the vent.

The hand dusting method was accomplished by dusting each bird individually, ruffling the material into the feathers to insure thorough penetration to the skin of the entire body.

For the flock dusting method a rotary hand duster was used. With this the birds were dusted at night when large pens were treated, although day treatment was practical for smaller pens.

In addition a limited number of spray tests were made with the most promising of the materials under consideration. These experiments were conducted with a 10 quart hand sprayer, producing a fine droplet spray. In spray tests with bis(p-chlorophenoxy methane) the material was applied as an aqueous suspension. Results of these tests were compared with those from a rather commonly used spray treatment employed in some poultry districts of California, namely, a 1.9 per cent nicotine sulphate solution using soap as a wetting agent. Whereas the bis(p-chlorophenoxy methane) spray was applied in drenching quantities, the nicotine sulphate was administered in amounts just sufficient to dampen the feathers.

The compounds used in the various tests were as follows: Parachlorophenyl phenyl sulfone (*Sulphenone*); Di-(p-chlorophenyl) methyl carbinol (*Dimite*); Beta-chloroethyl-beta-(paratertiary-butyl phenoxy)-alpha-methyl-ethyl sulfite (*Aramite*), Bis-(p-chlorophenoxy)-methane (*Neotran*); P-chlorophenyl p-chlorobenzene sulfonate (*Ovotran*); methoxychlor, toxaphene; DDT; lindane; sulphur, 325 mesh; nicotine sulphate (*Black Leaf 40*).

DISCUSSION OF RESULTS.—The data obtained from the preliminary screening tests with various dust formulations in petri dishes are given in table 1. From the results the most promising dust formulations were: 5 to 10 per cent *Neotran*, 0.5 per cent lindane, and 5 per cent methoxychlor. Moderately effective formulations were: 5 to 10 per cent DDT, 10 per cent toxaphene, 10 per cent *Sulphenone*, and 10 per cent *Ovotran*. Five per cent *Aramite*, although appearing moderately effective, seemed to have a repellent action which forced the mites into the water moat. Sulfur dust was ineffective. This is not surprising since the toxic action of sulphur to mites on the bird is probably associated with the production of H_2S when the material is subjected to the

Table 1.—Mortality of *Bdellonyssus sylviarum* in direct contact screening tests.[1]

Material Used	Per Cent Concentration	Replicates	Mite Activity[2] Days Post Treatment 1	2	3	4	5
Sulphenone	10	2	+	±		±	±
Aramite	5	1	+	+	−		
Aramite	5	1	+	+	+	±	−
Aramite	3	1	+		+		+
Neotran	10	2	−				
Neotran	5	2	+	−			
Ovotran	10	2	+	+	±	±	±
Toxaphene	10	1		±	±	±	±
Methoxychlor	5	2	±	±	−		
DDT	10	1	±	±	−		
DDT	5	2	±	±	±	±	−
Lindane	0.5	1	+		±		
Lindane	0.5	1	±	−			
Sulphur 325 mesh	100	2	+	+	+	+	+
Control	—	6	+	+	+	+	+

[1] For each test 100 or more mites were held on a dusted circle in a petri dish.
[2] + Mites active; ± Mites dead or moribund; − Mites dead.

relatively high body temperature of the fowl.

Screening tests of dust formulations against *Bdellonyssus sylviarum* on chicks are summarized in table 2. These tests were conducted to determine if various materials used could provide effective control on the normal host either through toxicity to the active stages of the mites or through ovicidal action.

Based on the data given in table 2, *Neotran* 10 per cent, and *Aramite* 5 per cent dust were effective. Methoxychlor 5 per cent dust appeared effective in an early test, but later using an impregnated dust, which would be expected to be more effective, rather erratic results were obtained. *Sulphenone* 10 per cent dust caused a marked reduction but no elimination of the mite population. Other materials tested were essentially ineffective. Not included in table 2 is one dusting test conducted on a heavily infested 9-day-old chick using 0.5 per cent lindane dust. This treatment effectively eliminated the infestation, but the chick was affected adversely for two days.

Upon comparing the results of the above chick-mite tests with those of the dish-type screening tests it is seen that *Neotran* at 10 per cent and *Lindane* at 0.5 per cent were effective by either method. Although methoxychlor appeared very effective in the "dish" test it was only moderately effective on the chick. *Sulphenone*, 10 per cent, and *Ovotran*, 10 per cent, which were moderately effective in the "dish" tests were ineffective on the chick. *Aramite*, of dubious effectiveness in the "dish" tests, was effective as a 5 per cent dust on chicks.

Table 2.—Results from dust formulations applied to chicks infested with *B. sylviarum*.[1]

Material Used	Per Cent Concentration	Replicates	Results[2] Days Post-Treatment 4–5	7	9–10
Sulphenone	10	1	−	+	±
Sulphenone	40	1	−		±
Dimite	10	1	+	+	+
Aramite	5	1	−	−	−
Aramite	3	1	+	−	+
Neotran	10	2	+	±	−
Neotran	1	2	+	+	
Ovotran	10	4	+	+	
Ovotran	5	1	±	+	+
Toxaphene	10	2	+	+	
Toxaphene	1	1	+	+	
Methoxychlor[3]	5	1	±	−	
Methoxychlor[4]	5	3	+	±	±
Lindane	0.10	1	+	±	
Lindane	0.05	1	+	+	
Inert dust	100	1	+	+	+
No treatment	—	4	+	+	+

[1] Each chick infested initially with 500 to 1000 mites.
[2] + mites numerous; ± very light infestation; − no mites seen.
[3] A dust prepared by mixing the diluent with methoxychlor.
[4] A dust prepared by impregnating the diluent with methoxychlor.

Several formulations appeared to be toxic to chicks when applied as dusts. In order to clarify the situation, further tests were conducted in which day-old chicks were treated with the formulations in question in the manner described for the mite tests. The chicks were observed for a minimum of 14 days after treatment. Results of these tests are given in table 3.

The data indicate that toxaphene 10 per cent dust is very toxic to chicks, although no ill effects resulted from 1 per cent Toxaphene. *Lindane* at 0.5 per cent stunted the growth of chicks and caused some mortality. This was accentuated at the 1 per cent level of application. Chlor-

Table 3.—Toxicity of dust formulations applied to day-old chicks.

Material Used	Per Cent Concentration	Number of Chicks Treated	Number of Chicks Surviving 14 Days
Aramite	5	6	6
Ovotran	10	7	6
Toxaphene	10	5	0
Toxaphene	1	5	5
Lindane	1	5	2
Lindane	0.5	5	3
Chlordane	5	5	4
Chlordane	2.5	5	3
Nicotine sulphate	2	5	5
Controls	—	6	5

Table 4.—Field tests for control of *Bdellonyssus sylviarum* on adult poultry.

Method of Treatment	Material Used	Per Cent Concentration	Number Birds Treated	Degree of Infestation[2] Days Post Treatment 0	7	14	21	28
Flock dusting	*Neotran*	10	1600	++	±	+		
		10	48	++	+	±	±	+
	Methoxychlor	5	1600	++	++	++	++	
Pinch dusting	*Neotran*	10	3	+	−	−	−	
Hand dusting	*Neotran*	10	6	++	−	−	−	−
	Methoxychlor	5	3	+	±	+	+	
	DDT	5	2	±	+	+	+	
	Lindane	0.5	3	+	+	+	±	
	Sulphur	99+	32	+	−	−	−	
Flock spraying	*Neotran*	0.5	24	++	±	±	±	±
	Neotran	1	24	++	±	−	±	±
	Neotran	1	120	++	+	+		
	Neotran	1.5	12	++		±	±	±
	Neotran	2	12	++	±	±	±	±
	Neotran	2	24	+	±	−	−	−
	Neotran	2	12	++	±	±	±	
	Nicotine sulphate	1.9	24	++	±	±		
		1.9	24	++	−	−	±	±

[1] Results of a flock treatment were determined by weekly examination of 4 to 12 banded birds.
[2] ++ infestation; + moderate; ± light; − no mites seen.

dane at 2.5 and 5 per cent caused some mortality among treated chicks. Ten per cent *Ovotran* dust is believed to be nontoxic to chicks. Of seven treated chicks one died on the 14th day, but this is believed due to accidental chilling of the chicks on the preceding day.

The results of field tests on adult chickens with dust formulations for the control of *Bdellonyssus sylviarum* are given in table 4. Ten per cent neotran produced only temporary reduction of infestation when applied by the flock dusting method, but proved very effective when dusted into the feathers by hand. The latter treatment also appeared to provide protection from reinfestation since treated birds held with infested untreated fowl did not become reinfested over a four-week observation period. Ten per cent *Neotran* dust was also effective when applied by the pinch method as described earlier. Sulphur (325 mesh) gave effective control when thoroughly applied by hand dusting. Five per cent methoxychlor dust proved ineffective when used by either the flock dusting or hand dusting method. Lindane at 0.5 per cent and DDT at 5 per cent were ineffective when applied by hand dusting, although the degree of infestation was reduced. The results with DDT reported here verify the findings of Povar (1946).

It seems obvious from these data that the flock dusting method used is ineffective in actually bringing dust in contact with the parasites. There appears to be no simple solution to this problem with regard to flock dusting methods unless the material used has a sufficiently high vapor pressure to exert a fumigant effect. The most effective method used for assuring contact between dust and mite was the hand-dusting technique.

Since individual handling of birds is time consuming, limited tests were conducted on adult fowl with a spray application of neotran, the most effective material used in dusting procedures. Data obtained from these tests are given in table 4. Within the range of 0.5 to 2 per cent, neotran suspensions gave erratic results when applied by the flock-spray method. Apparently 100 per cent control of mites was obtained in some cases, but in others occasional birds in pens, otherwise under good control, maintained light to moderate infestations. The probable explanation of these results is that in flock spraying some birds inevitably receive less than the amount of spray required for control. It appears that the birds must be thoroughly wet with spray.

The results with a 2 per cent nicotine sulphate flock-spray indicate that marked but temporary reduction of fowl mite populations are obtained.

SUMMARY AND CONCLUSIONS.—Eleven materials were evaluated for effectiveness against the northern fowl mite, *Bdellonyssus sylviarum* (Can. Fanzago). Laboratory screening tests of two types were conducted to evaluate the effectiveness of the materials both off and on the normal host of the mite. Field tests were conducted with the most promising materials.

The most effective material on the basis of laboratory tests was bis-(p-chlorophenoxy)-methane (neotran). By the pinch-dusting or hand-dusting method, a 10 per cent *Neotran* dust not only eliminated infestations from adult chickens in field tests but apparently provided protection against reinfestation for at least 28 days. The flock-dusting of adult birds with a hand duster did not provide effective penetration of dust into the feathers and thus adequate control was not obtained by this method.

Single spray treatments of poultry flocks with suspensions of neotran at concentrations ranging from 0.5 to 2 per cent gave erratic control of the northern fowl mite, although infestations were usually markedly diminished. Further investigation of this method of application seems warranted. Single, light spray applications of poultry with a 1.9 per cent nicotine sulphate solution with soap as a wetting agent produced moderate but temporary reduction of mite populations.

Thorough hand treatment of chickens with 325 mesh sulphur resulted in effective control in a flock having a moderately heavy infestation of northern fowl mites. A 5 per cent dust of beta-chloroethyl-beta-(para-tertiary-butyl phenoxy) -alpha-methylethyl sulfite (Aramite) provided effective control of mites in laboratory tests on chicks. Future field tests of this material are warranted.

Materials of some promise on the basis of laboratory tests, but which were ineffective when applied as dusts to adult birds in field tests were as follows: 5 per cent methoxychlor, 5 per cent DDT, and 0.5 per cent lindane.

Materials showing only moderate to slight effect as dust formulations against *Bdellonyssus sylviarum*, on the basis of laboratory tests, were 10 per cent para-chlorophenyl phenylsulfone (*Sulphenone*), 10 per cent di-(p-chlorophenyl) methyl carbinol (*Dimite*), 10 per cent p-chlorophenyl p-chlorobenzene sulfonate (*Ovotran*), and 1 to 10 per cent toxaphene.

Materials appearing toxic to chicks when applied as dusts were as follows: 10 per cent toxaphene, 0.5 to 1 per cent lindane and 2.5 to 5 per cent chlordane.

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Relation of Corn Earworm Resistance in Sweet Corn to Efficiency of Insecticide Sprays

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The corn earworm, *Heliothis armigera* (Hbn.), has been a limiting factor in the production of sweet corn in the Lower Rio Grande Valley of Texas. In the past earworm damage has been so severe that yields averaged only 15 to 60 half-bushel sacks per acre. Because of this severe earworm injury, experiments were conducted to determine whether the use of earworm resistant hybrids would aid the grower in his earworm program, which today includes the use of insecticides. The use of earworm resistant hybrids would be of great value in this area because the grower would then be able to harvest more marketable corn from that portion of the field which he was unable to spray properly. Two experiments were conducted, one in 1949 and the other in 1950, to obtain data on the subject.

MATERIALS AND METHODS.—The sweet corn in the first experiment was planted on August 15, 1949, near Raymondville, in an area that always has severe earworm infestations. Each of the six strains shown in table 1 was planted in eight-row blocks, the rows being a quarter of a mile long and spaced 3 feet apart. Each insecticide treatment was applied to two rows in each block as shown in the table. The strains in the second experiment, shown in table 2, were planted at Weslaco on February 20, 1950, in double-row plots 75 feet long, with the rows spaced 3 feet

Table 1.—Effect of natural earworm resistance of sweet corn on the efficiency of DDT-oil sprays used for the control of the corn earworm. Raymondville, Texas, Fall, 1949.

Hybrid	Per Cent of Ears Classified According to Earworm Damage		
	Clean	Marketable	Culls
DDT-Oil Emulsion,[1] 3 Applications			
Calumet	90	10	0
Dixie Gold	77	23	0
Erie	87	10	3
Golden State	64	33	3
Hybrid 2439	43	40	17
Ioana	67	30	3
DDT-Oil Emulsion,[1] 2 Applications			
Calumet	73	27	0
Dixie Gold	70	30	0
Erie	60	30	10
Golden State	57	37	6
Hybrid 2439	43	40	17
Ioana	37	40	23
DDT-Oil,[2] 1 Application			
Calumet	67	30	3
Dixie Gold	80	10	10
Erie	57	37	6
Golden State	77	13	10
Hybrid 2439	65	10	25
Ioana	33	44	23
Untreated			
Calumet	0	57	43
Dixie Gold	0	20	80
Erie	0	43	57
Golden State	0	50	50
Hybrid 2439	0	20	80
Ioana	0	13	87

[1] DDT 1%+oil 10% plus water.
[2] DDT 1%+oil 99%.

Table 2.—Effect of natural earworm resistance of sweet corn on the efficiency of DDT-oil sprays used for the control of the corn earworm. Weslaco, Texas, Spring, 1950.

Hybrid	Per Cent of Ears Classified According to Earworm Damage		
	Clean	Marketable	Culls
DDT-Oil Emulsion,[1] 3 Applications			
Calumet	88	5	7
Flagship	85	8	7
Golden State	94	3	3
Golden Supreme	79	18	3
Ioana	94	3	3
KVF 47-10	68	25	8
KVF 49-25	87	8	5
KVF 49-45	85	3	12
Seneca Chief	90	8	2
DDT-Oil Emulsion,[1] 2 Applications			
Calumet	70	23	7
Flagship	87	8	5
Golden State	75	13	12
Golden Supreme	57	28	15
Ioana	62	27	11
KVF 47-10	52	12	36
KVF 49-25	62	15	23
KVF 49-45	58	28	14
Seneca Chief	90	8	2
Untreated			
Calumet	18	72	10
Flagship	40	47	13
Golden State	28	42	30
Golden Supreme	10	53	37
Ioana	10	40	50
KVF 47-10	10	32	58
KVF 49-25	10	62	28
KVF 49-45	12	55	33
Seneca Chief	10	57	13

[1] DDT 1%+oil 10%+water.

apart. Each plot was then sub-divided into three parts and treated as shown in the table. The Weslaco area generally has lighter earworm infestations than surrounding areas. Since Ioana was the commonly grown strain at the time of these experiments, it was used as the standard for comparison of earworm resistance among the strains. A severe earworm infestation was considered as one where the earworms injured or destroyed 1.5 inches or more of the ear tips on 75 per cent of the ears. In moderate earworm infestation the earworm caused 1.5 inches or more damage to 50 per cent of the ears.

The insecticide spray used in the two and three application treatments was made up in quantities of 2 gallons, using the following formula; 1 gallon of 25–per cent emulsifiable DDT, 2.5 gallons of pure mineral oil of 90 seconds Saybolt viscosity, and water to make 25 gallons. The emulsion was well agitated and then sprayed directly on the silks of the ears and also on the ear shoots at approximately 1.5 cc. per ear. Silking records were taken and the first application was made to each hybrid in the test when approximately 15 per cent of the plants showed silks. In the two application treatments an interval of 3 days elapsed between treatments. In the treatment with three applications an interval of 2 days elapsed between treatments.

The spray used in the single application was made by dissolving 2 pounds of technical DDT in 15 gallons of mineral oil. This solution was sprayed on the silks at approximately 1 cc. per ear when silking data showed that 90 per cent of the plants were silking. It was applied only once because experiments had shown that excessive amounts of oil prevented the development of kernels on the tips of ears.

Both sprays were applied with a 3-gallon hand garden sprayer. A pressure gauge was mounted on the sprayer and the pressure kept at 40 to 50 pounds per square inch during applications. A low pressure nozzle with an orifice of 0.042 inch diameter was used in applying the emulsion and one having an orifice of 0.028 inch diameter was used in applying the DDT in oil.

The earworm damage in these experiments was classified as follows: Clean ears —those showing no earworm feeding on the tips and having no living larvae in the silk channels; marketable ears— those having up to 1.5 inch earworm feeding on the tips of the ears, or ears with live larvae in the silk channels—such ears can be trimmed and sold as U. S. No. 1 clipped ears; and cull ears—those having 1.5 inch or more earworm injury on the tips and which when trimmed are usually too short to be graded as U. S. No. 1 clipped ears.

DISCUSSION.—Ioana, at the time of these experiments, was the most common sweet corn strain grown in the Lower Rio Grande Valley. The data in tables 1 and 2 show that untreated Ioana is very susceptible to earworm attack. In the first experiment a heavy population of earworms caused 87 per cent of the ears of this strain to be classified as culls. Eighty per cent of the ears were ruined by earworms in Hybrid 2439 and Dixie Gold plots, while 43 per cent of the ears were culls due to earworm damage in Calumet, 50 per cent in Golden State and 57 per cent in Erie. In the second test, seven of the eight strains (grown for comparison with Ioana) apparently had more natural earworm resistance than Ioana under the moderate infestation occurring in the plots. Only 10 and 13 per cent of the ears were culls in the untreated plots of Calumet and Flagship, respectively, as compared with 50 per cent as culls in the untreated Ioana plots.

In the 1949 test, the single application of DDT in oil injured 10 per cent of the ear tips in Ioana and resulted in only 33 per cent worm-free ears. Dixie Gold and Golden State yielded 73 per cent or more worm-free ears when sprayed with this DDT-oil formulation but 30 percent or more of the ears were severely injured by the oil. In the Calumet plots 67 per cent of the ears were free from earworm damage after a single application of the DDT-oil spray treatment but 30 per cent of the ears showed oil damage on the tips. Since the time of these experiments almost all sweet corn growers in the Valley have changed from Ioana to Calumet for the following reasons: 1) More worm-free ears are obtained in Calumet fields from a single application of 1 per cent of DDT in mineral oil than in the Ioana fields; and 2) under normal earworm infestations growers are able to harvest more marketable ears in untreated fields planted to an

earworm resistant strain such as Calumet than in untreated Ioana fields.

The data in table 1 show that under severe earworm infestations two applications of the DDT-oil emulsion were about as effective as the single application in controlling corn earworms on Ioana, Calumet and Erie, whereas better control was obtained with the single application of DDT in oil than with two applications of the DDT-oil emulsion on strains of Dixie Gold, Golden State and Hybrid 2439. Three applications of the DDT-oil emulsion were more effective than two applications on all strains except Hybrid 2439, on which the two and three treatment applications were equal in effectiveness.

Under severe earworm infestations better results were obtained with sprays on Calumet, Dixie Gold, Erie and Golden State, than on either Ioana or hybrid 2439. Under much lighter earworm infestations, as shown in table 2, the response of Ioana to three applications of the DDT-oil emulsion in controlling earworms was equal to that of Golden State, Seneca Chief, Calumet, Flagship, KVF 49–25 and KVF 49–45. The DDT-oil emulsion spray did not give as effective control of earworms on Golden Supreme and KVF 47–10 as it did on Ioana under low earworm infestations, as shown in table 2. The data in this table also show that two applications of the DDT-oil emulsion were as effective as three applicaions in controlling earworms on Seneca Chief and Flagship whereas three applications gave better control on the remaining hybrids. Sprays on the DDT-oil emulsion gave about the same control on Calumet for both the severe and moderate earworm infestations whereas the percentage of control by sprays on Ioana was influenced by the degree of earworm infestation.

SUMMARY.—The data show that Calumet and Flagship sweet corn have more natural resistance to the corn earworm than Ioana, which until recently was the most commonly grown strain in the Lower Rio Grande Valley of Texas.

A single application of 1 per cent of DDT in oil controlled 70 per cent of the earworms on Calumet, which is considered commercial earworm control, and only 33 per cent on Ioana. However, this DDT in oil application damaged approximately 30 per cent of the ear tips.

Under severe infestations, three applications of an emulsion containing 1 per cent of DDT and 10 per cent of oil gave better earworm control on Calumet, Erie and Dixie Gold than on Ioana, Golden State, or Hybrid 2439.

Under conditions of moderate earworm infestations, three applications of a spray emulsion containing 1 per cent of DDT and 10 per cent of oil controlled earworms equally well on Ioana, Calumet, Seneca Chief, Golden State, Flagship, KVF 49–45 and KVF 49–25. Three applications of the same spray did not give as good results on Golden Supreme or KVF 47–10. Under the same type of infestation, two applications were as effective as three when applied to Flagship and Seneca Chief. Better earworm control was obtained on the remaining hybrids with the use of three applications of the DDT-oil emulsion than with two. It has been the observation of the writers that with severe infestations in untreated commercial fields the percentage of cull ears harvested was usually less on earworm resistant hybrids, such as Calumet or Fagship, than on other hybrids.

BRANCH MEETINGS

The following meetings have been announced.

Eastern—Lord Baltimore Hotel, Baltimore, Maryland
November 24 and 25, 1952

Southwestern—Hotel Galvez, Galveston, Texas
February 26 and 27, 1953

North Central States—Hotel Statler, St. Louis
March 19 and 20, 1953

Cotton States—Hotel Jung, New Orleans, Louisiana
February 9–11, 1953

Pacific—Lake Tahoe, Idaho
June, 1953

Control of Pear Psylla[1]

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Populations of over-wintering pear psylla, *Psylla pyricola* Forster, adults observed during the last few years have been moderate in western New York orchards, and egg deposition during any one season appeared correspondingly light. It was noticeable, however, that these light to moderate infestations commonly increased during the summer months to dangerous proportions, and extensive foliage injury and smutting of the fruit resulted.

In previous years the control of this insect through the destruction of the over-wintering adults with an oil spray during the dormant period frequently was uncertain. This situation is attributed to variation in adult emergence and also to ground or weather conditions which are often unsatisfactory for making spray applications. One or more supplementary treatments with nicotine often were necessary, but this increases the cost of control.

The experimental work discussed below was carried on to find among the newer materials a treatment sufficiently effective in the dormant period to prevent or greatly reduce the development of the first brood and so destroy the potential for later build-up. It also was attempted here to determine the most critical time to apply treatments. Because the efficiency and safeness of certain so-called "dormant" control sprays may vary according to the degree of bud development early in the season, it was felt that sprays might well be applied at either one of two distinct bud stages designated as "early dormant" and "late dormant." In this report the early dormant period is considered to extend from the time the fruit buds are in the tight winter stage until they have begun to swell appreciably showing definite loosening of the bud scales. The late dormant period continues from this point on and ends when bud development has reached the stage in which the terminal bud scales have separated, exposing the yellowish bracts and an occasional green leaf tip.

Most of the treatments described below were applied during the late dormant period. By this time many eggs had been deposited, and over-wintering adults were active in the orchards. All applications were made from the ground with conventional high pressure equipment, and in each experimental planting one or more check trees were left along each border. Effectiveness of control was determined on the basis of numphs surviving the treatments. Except for the tests in 1949 and the summer treatments in 1950, control data were obtained from egg-bearing spurs removed from the leeward sides of the center trees of each plot directly after the application. These were placed in individual vials of water in the insectary to prevent further egg deposition, parasite activity and complications arising from other hazards. The minimum number of spurs under observation per treatment was 16 and the maxiium, 50, Each spur was examined at least twice under a binocular microscope to determine the condition of the eggs, extent of hatching, survival of nymphs and the amount of parasitism. Usually it was not possible to examine all of the spurs under test at any one time, but every effort was made to obtain records on a representative number of spurs at each examination period.

The materials, dosages and other pertinent data are shown in tables 1 to 6. Most of the materials used were standard insecticides; parathion, EPN and several other phosphorous compounds were tested here for the first time.

Tests in 1948.—Experiments were carried on during the late dormant period in two Bartlett pear orchards which had been heavily infested the previous year. Five spray mixtures were applied to plots of 12 trees each in the first orchard. Because of windy conditions, only 3 single plots were sprayed in orchard 2. These consisted of 3 rows each extending across the orchard into the general direction of the wind at spraying time. In evaluating the data from this orchard consideration should be given to the probable effect of drifting spray, especially where parathion is concerned. It will be noted from a study of tables 1 and 2 that the control obtained with all materials, except for

[1] Journal Paper No. 892, New York State Agricultural Experiment Station, Geneva, N. Y., March 20, 1952.

Table 1.—Results of sprays applied April 19 for pear psylla control in orchard 1, 1948.

MATERIAL AND AMOUNT PER 100 GALLONS	NO. DAYS AFTER SPRAY	PER CENT EGGS INJURED	PER CENT EGGS HATCHED	PER CENT NYMPHS SURVIVED
Triethanolamine salt of dinitro sec. butyl phenol (36%)[1]				
	10	7.8	0	0
2.4 qts.	18	46.9	0	0
	25	60.0	0	0
	12	10.4	.4	.4
1.6 qts.	18	39.5	.8	.4
	24	42.0	1.8	.4
Dinitro-o-cresol (40% w.p.)[2]				
	10	4.5	1.9	1.9
4 lbs.	18	89.4	2.6	.9
	25	89.4	2.8	.9
	12	11.9	3.3	.5
3 lbs.	18	83.5	4.1	1.0
	23	83.5	8.6	1.8
Superior dormant oil[3]—12 qts.	12	2.8	0.0	0.0
	18	40.9	38.3	4.5
	25	44.5	44.8	5.2
Average of checks	14	4.1	61.0	59.0
	18	10.3	86.7	77.9
	28	12.9	86.7	77.9

[1] DN-289. Dow Chemical Company.
[2] DN. Dry mix No. 2. Dow Chemical Company.
[3] For specifications see JOUR. ECON. ENT. 42(45): 1949.
An average of 366 eggs was examined per treatment.

BHC, was very satisfactory. Only a few hatched eggs were observed on spurs from plots receiving the triethanalomine salt of dinitro sec. butyl phenol, dinitro-o-cresol or parathion. Many eggs hatched on both oil and BHC treated spurs, but very few nymphs survived where the oil was used. Most of the nymphs were killled through contact with the oil film as they crawled over the bark in search of feeding places. The effect of the sprays on the eggs was scarcely noticeable during the first week or 10 days, but beyond that time, as shown in the tables, visible egg damage became progressively more evident. The discoloration and collapse of the eggs were especially prominent in the plots sprayed with the dinitro materials however, the severe damage to eggs treated with parathion indicates that phosphorous products also may have ovicidal value.

TESTS IN 1949.—Two experimental plots in a Bartlett orchard were sprayed

Table 2.—Results of sprays applied April 20 for pear psylla control in orchard 2, 1948.

MATERIAL AND AMOUNT PER 100 GALLONS	NO. DAYS AFTER SPRAY	PER CENT INJURED	PER CENT EGGS HATCHED	PER CENT NYMPHS SURVIVED
Parathion (25% w.p.)—.75 lb.	14	26.5	.4	0
	17	57.1	1.1	0
	27	82.0	1.1	0
Superior dormant oil[1]—8 qts.	14	22.6	.5	.5
	20	61.3	11.8	.5
	28	77.4	19.4	.5
BHC (6% gamma isomer)—2 lbs.	15	28.8	20.0	3.8
	17	54.6	36.2	15.8
	29	54.6	36.2	15.8
Average of checks	17	12.7	77.3	77.3
	29	12.7	83.6	77.3

[1] For specifications see JOUR. ECON. ENT. 42(45): 1949.
An average of 324 eggs was examined per treatment.

Table 3.—Results of sprays applied April 12 for pear psylla control in 1949, with two exceptions.[1]

MATERIAL AND AMOUNT PER 100 GALLONS	NO. DAYS AFTER SPRAY	PER CENT EGGS INJURED	PER CENT EGGS HATCHED	PER CENT NYMPHS SURVIVED
Triethanolamine salt of dintro sec. butyl phenol (36%)[2]—2 qts.	7	10.2	0.0	0.0
	36	81.4	.8	.4
	57	96.7	.8	0.0
Sodium salt of dinitro-o-cresol (22%)[3]				
	7	8.3	0.0	0.0
4 qts.	36	84.2	2.9	2.9
	57	77.9	17.3	17.3
	7	5.4	0.0	0.0
3 qts.	36	67.5	8.9	6.2
	57	92.8	8.9	.9
	7	4.5	0.0	0.0
2 qts.	36	70.2	2.3	1.6
	57	92.8	2.3	0.0
3 qts.[1]	15	9.6	0.0	0.0
	43	63.1	30.0	29.0
3 qts.[1]	15– 7	10.5	0.0	0.0
Superior dormant oil[4]—2 gals.	43–36	66.2	9.7	9.7
Parathion (25% w.p.)—.75 lb.	7	2.8	0.0	0.0
	36	82.0	6.6	6.6
	57	90.7	8.5	4.2
Superior dormant oil—2 gals	7	1.9	0.0	0.0
	36	48.5	47.4	19.4
DDT (50% w.p.)—1.5 lbs.	7	4.8	0.0	0.0
Superior dormant oil—2 gals.	36	42.0	53.6	35.6
BHC (6% gamma isomer)—2.5 lbs.	7	5.9	0.0	0.0
	36	20.8	75.6	74.1
Average of checks	7	2.3	0.0	0.0
	36	26.3	68.3	57.8

[1] Applied 4/5.
[2] DN-289. Dow Chemical Company.
[3] Elgetol. Standard Agricultural Chemical Company.
[4] For specifications see JOUR. ECON. ENT. 42(45): 1949.
An average of 480 eggs was examined per treatment.

with the sodium salt of dinitro-o-cresol on April 5 when the buds were in the early dormant period. A week later when the buds were in the late dormant stage nine additional treatments were applied in the same orchard. At this time half of each plot previously treated with the dinitro material was sprayed with an oil emulsion. The data this season were taken from spurs which were not removed from the trees until the time of examination. There was nothing, therefore, to prevent the movement of psylla flies from one plot to another, and observations made May 11 showed that adults of the first brood were beginning to oviposit on the new foliage. For this reason the data from only the second series of spur examinations were used in the calculation of efficiencies. The results are shown in table 3. It will be noted that the control with most of the dinitro sprays applied on April 12 was good, ranging from about 90 per cent for the sodium salt of dinitro-o-cresol at 3 quarts per 100 gallons to 99 per cent for triethanolamine salt of dinitro sec. butyl phenol at 2 quarts. In most tests with these materials and also parathion in the late dormant period, egg hatching was light and few nymphs survived. In the oil plots also sprayed April 12 it will be noted that about 50 per cent of the eggs hatched but a high mortality of nymphs again resulted from contact with the oil film on the bark. Parathion was less effective than the dinitro sprays, but control was good considering the low survival in the checks. It should again be noted that the percentage of eggs showing injury in the treated plots increased markedly between 7 days and 36 days after treatment.

TESTS IN 1950.—On April 26, five late dormant treatments were applied in an orchard of Seckel pears. Each plot consisted of about 12 mature trees. Directly after spraying about 50 spurs were taken from each plot and brought to the in-

Table 4.—Results of sprays applied April 26 for pear psylla control, 1950.

Material and Amount per 100 Gallons	No. Days After Spray	Per Cent Eggs Injured	Per Cent Eggs Hatched	Per Cent Nymphs Survived
Parathion (25% w.p.)				
	15	15	4.1	0.0
1 lb.	21	44.2	4.2	0.0
	50	72.6	4.8	.1
	19	37.6	15.1	1.2
.5 lb.	23	39.4	5.0	1.9
	50	66.4	6.3	1.9
Triethanalomine salt of dinitro	21	18.0	2.9	.5
sec. butyl phenol (36%)[1]—1.6	50	55.8	2.3	1.6
qts.	56	62.1	0.0	0.0
Sodium salt of dinitro-o-cresol	16	8.3	.7	.7
(22%)[2]—3 qts.	21	22.8	.8	.8
	50	72.9	1.0	.8
BHC (6% gamma isomer)—2.5	19	13.5	70.8	65.9
lbs.	26	34.0	44.3	32.0
	50	44.0	47.1	36.8
Average of checks	15	4.2	75.8	75.8
	21	11.8	64.7	58.8
	50	12.2	79.4	—

[1] DN-289. Dow Chemical Company.
[2] Elgetol. Standard Agricultural Chemical Compar v.
An average of 438 eggs was examined per treatme .

Table 5.—Results of sprays applied July 14 for pear psylla control, 1950.

Material and Amount per 100 Gallons	Series Number	No. Days After Spray	Per Cent Eggs Injured	Per Cent Nymphs Survived
Parathion (15% w.p.)				
27 ozs.	1	15	43.1	0.0
	2	16	55.7	.4
14 ozs.	1	8	17.5	0.0
	2	11	11.1	3.4
Malathon (47.7% emul.)[1]				
40 fl. ozs.	1	6	50.7	0.0
	2	15	35.4	0.0
20 fl. ozs.	1	7	16.3	0.0
	2	14	74.1	4.2
S-(1,2-dicarbomethoxyethyl)				
o,o-diethyl dithiophosphate	1	6	34.1	0.0
(47.7% emul.)[2]—10 fl. ozs.	2	11	27.6	1.9
0-(2-chloro-4-nitrophenyl)-				
o,o-dimethyl dithiophosphate	1	5	00.0	.8
(25% emul.)[3]—10 fl. ozs.	2	13	55.6	3.2
EPN (27% w.p.)[4]—8 ozs.	1	12	32.1	.6
	2	16	47.7	0.0
Metacide (30% emul.)—8 fl. ozs.	1	6	00.0	2.0
	2	12	36.9	0.0
Ground derris root—2 lbs.	1	14	36.6	4.2
Summer oil—64 fl. ozs.	2	15	33.3	7.1
CS708—32 ozs.	1	13	37.7	6.9
	2	15	38.8	9.7
2,4-dinitro-6-sec.-octyl phenyl	1	11	9.1	39.4
crotonate (25% w.p.)[5]—16 ozs.	2	15	7.8	26.1
Dow 1006	1	8	00.0	61.3
	2	14	12.5	44.1
Average of checks		5-18	12.9	81.1

[1] American Cyanamid Company.
[2] 4018. American Cyanamid Company.
[3] 4124. American Cyanamid Company.
[4] EPN-300. E. I. duPont de Nemours &Company, Inc.
[5] Karathane. Rohm and Haas Company.
An average of 171 eggs was examined per treatment.

Table 6.—Results of sprays applied April 24 for pear psylla control, 1951, with two exceptions.[3,4]

Material and Amount per 100 Gallons	No. Days After Spray	Per Cent Eggs Injured	Per Cent Eggs Hatched	Per Cent Nymphs Survived
Malathon (50% emu.)[1]				
10 fl. ozs.	21	10.0	86.0	3.3
	42	15.4		
13 fl. ozs.	21	13.5	73.7	2.6
	41	19.7		
16 fl. ozs.	24	25.2	46.0	.9
	48	42.3		
18 fl. ozs.	24	26.9	47.5	.6
	48	40.8		
20 fl. ozs.	20	17.0	72.2	.4
	35	27.0		
Parathion (15% w.p.)				
12 ozs.	22	56.2	4.1	2.8
	43	84.3		
16 ozs.	17	26.1	5.9	4.2
	31	73.6		
	52	90.4		
20 ozs.	27	65.2	2.8	.6
	50	91.0		
24 ozs.	23	73.9	3.1	1.2
	48	87.8		
Parathion (15% w.p.)[2]				
16 ozs.[3]	19	47.2	11.4	0.0
	44	63.8		
16 ozs.[4]	21	59.7	.7	0.0
	45–43	77.7		
32 ozs.[3]	16	61.8	21.3	.8
	36	71.1		
EPN (25% w.p.)[5]				
8 ozs.	23	55.0	11.0	5.8
	49	82.7		
12 ozs.	23	52.7	3.8	.5
	49	91.2		
Triethanalomine salt of dinitro sec. butyl phenol (36%)[6]				
48 fl. ozs.	22	26.5	4.6	4.2
	43	63.4		
64 fl. ozs.	22	28.3	1.0	.2
	43	79.2		
Sodium salt of dinitro-o-cresol (22%)[7]				
64 fl. ozs.	20	21.2	9.9	6.3
	31	58.1		
	51	77.2		
96 fl. ozs.	27	40.7	3.5	3.2
	43	77.1		
128 fl. ozs.	20	21.9	2.6	2.3
	35	54.7		
Check	17	3.1	82.5	82.3
	31	8.6	91.1	89.4

[1] American Cyanamid Company.
[2] Tobacco By-Products Corporation. Applied 4/30.
[3] Applied April 30.
[4] Applied April 30 and May 2.
[5] EPN-300. E. I. duPont de Nemours and Company, Inc.
[6] Elgetol 318. Dow Chemical Company.
[7] Elgetol. Standard Agricultural Chemical Company.
An average of 745 eggs was examined per treatment

sectary were the same technique was followed as in 1948. Table 4 shows the results. It will be noted that both the dinitro and parathion sprays were highly effective, and that these sprays at all dilutions were extremely toxic to eggs laid by the over-wintering adults. The data also indicate that parathion may have some residual effect on the nymphs.

On July 14 a series of 12 treatments were applied in a Bartlett orchard, each sprayed plot consisting of about 12 trees. Some adult psylla were present at the time, but early instar nymphs and eggs predominated. One series of 5 to 8 spurs was collected from each plot directly after the spray and a second series about 10 days later. The results are shown in table 5. It will be seen that the phosphorous materials were highly effective

against both the eggs and the nymphs, giving such complete control that the differences in effectiveness shown by the data of the two series of spur collections were negligible. The great amount of egg damage apparent within the short period after treatment indicates that the phosphorous materials are especially toxic to summer eggs.

Parasitism was light in plots treated with malathon and S-(1,2-dicarbomethoxyethyl)-o,o-diethyl dithiophosphate; also for parathion and diethyl-p-nitrophenol-thiophosphate, and with rotenone and oil, ranging between 1.8 and 3.9 per cent. In the remaining plots it varied between 7.7 and 14 per cent. In the check plots it was between 4.5 and 12 per cent. The parathion plots treated with 14 ounces of the material showed the highest amount of parasitism followed by 2-nitro-1,1-bis(p-chlorophenyl)butane; CS-708 with 13.6 per cent.

TESTS IN 1951.—Tests with dinitro materials and also phosphorous formulations were continued in 1951. Single plots of several trees each were sprayed as in previous seasons, and infested spurs were brought to the insectary for observation. Two examinations were made of each spur, the results of which are shown in table 6.

It will be noted that parathion, 15% wettable powder, used at 12 ounces in 100 gallons gave good control, but that the 20-ounce rate was definitely more effective. Parathion formulated by the Tobacco By-Products Corporation, used at 16 ounces in 100 gallons, gave excellent control with both 1 and 2 treatments. Malathon gave good control at 10 ounces in 100 gallons and excellent control at 16 ounces. An observation worthy of note here is that a comparatively high percentage of eggs treated with this material hatched but that nymphal mortality in the case of each test was sufficiently great to produce the high control shown in the table. Also, as previously observed the injurious effect of the materials on the eggs was much more noticeable at the second examination that at the first.

DISCUSSION.—The standard dinitro materials, parathion and other phosphorous compounds, applied during the late dormant periods of 1948, 1950 and 1951 were highly effective against pear psylla. Oil sprays also gave good control when applied at this time. The late dormant period is apparently the optimum time to originate psylla control treatments. Parathion, other phosphorous compounds and ground derris root with oil were also very effective when applied under summer conditions. Control by dormant sprays resulted in most cases from the ovicidal action of the material, although parathion showed some residual action. Malathon was distinctive in its effectiveness on psylla. It either severely weakened the developing embryos or left residues extremely toxic to the young nymphs. While oil sprays were somewhat toxic to the eggs, such materials act principally against the newly hatched nymphs. Considering the great potential for rapid build-up of psylla populations, it seems advisable to recommend dosages greater than the minimum shown in these tests. Of various materials that are suitable for early season control of pear psylla, the following dosages are suggested for 100 gallons: sodium salt of dinitro-o-cresol, 3 quarts; triethanolamine salt of dinitro sec. butyl phenol, 2 quarts; superior dormant oil, 2 gallons; parathion (15% w.p.), 1.25 pounds; and malathon, 50 per cent emulsion, 1.25 pints.

Insect Injury to Blackeye Bean Seeds in Central California

WOODROW W. MIDDLEKAUFF[1] and E. E. STEVENSON[2]

Blackeye beans are grown extensively in the warmer interior valleys of southern and central California where they are a very important field crop. Despite reductions in plantings since the war the acreage devoted to blackeyes is still quite large. A statewide planting of 66,000 acres during the 1950 season produced over 610,000 one hundred-pound bags of cleaned beans. This places the total blackeye acreage next to that of baby and large lima beans which rank first and second. Stanislaus County in the San Joaquin Valley has been a heavy producer of blackeyes and during the years 1947 to 1951, has averaged over 21,000 acres in production with an average yield during this period of 202,510 one hundred-pound bags.

It has not been the general practice to apply insecticides to blackeyes in the San Joaquin Valley and as a result the growers have been heavily penalized because of the excessive amount of insect injury occurring in their blackeyes. In years of strong demand these growers can sell even the heavily injured beans for a satisfactory price, but with high production and lower demand insect damaged beans are hard to sell. Quality beans command premium prices.

A number of species of insects feed upon the blackeye seed during its development and cause visible defects which materially lessen the value of the crop. The most important species in central California causing defective seeds are the plant bugs, *Lygus hesperus* Knight; *Lygus elisus* Van Duzee; the corn earworm, *Heliothis armigera* (Hbn.); the lima bean pod borer, *Etiella zinckenella* (Treit.) and the western yellow striped armyworm, *Prodenia praefica* Grote. The cowpea weevil, *Callosobruchus maculatus* (F.) infests beans in the field but is considered to be primarily a pest of the stored product.

The purpose of the following surveys and experiments was to determine the importance of the above insect pests and to initiate control experiments with the view of improving seed quality. All fields mentioned in this report were located in Stanislaus County, California.

HISTORICAL.—Necrotic lesions on dry edible beans were first associated with the feeding of the eastern (*Lygus pratensis* L.) = *Lygus oblineatus* (Say) in Michigan in 1895 by Davis (1897). This association was proven experimentally in New York in 1919 by Hawley (1922). Shull & Wakeland (1931) and Shull (1933) reported typical symptoms on several varieties of beans including baby limas in Idaho. Baker & Snyder (1946) definitely associated seed pitting of limas and blackeyes with lygus bugs in California in 1944 and demonstrated that these or comparable symptoms which are frequently attributed to a yeast (nematospora) in the southeastern United States are caused by lygus in California since no nematospora or other pathogens were ever found in California material. They also indicated that *Lygus hesperus* and *L. elisus* are the two species causing damage in California.

References to damage caused by lepidopterous larvae to blackeyes are very scarce. Mackie (1946) states that the lima bean pod borer is known to attack blackeyes and he considers the corn earworm to be of little economic importance.

METHODS AND MATERIALS.—A number of growers throughout the county were encouraged to dust their fields of blackeyes with either 5 per cent DDT or 10 per cent toxaphene for lygus and worm control. Samples were taken from nineteen of these fields at harvest time and 500 seeds from each sample were examined for insect injury. A similar series of samples were taken and examined from twenty undusted fields. The undusted fields were selected as being the closest to the above treated fields.

In addition four small plots approximately one acre in size, each located in an undusted field, were treated with 5 per cent DDT-50 per cent sulfur by means of rotary hand dusters.

Treatment data and a description of the small plots are as follows:

Small Plot 1.—A small block 90 rows

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deep and 250 feet wide was treated on September 12, 1951 at approximately 29 pounds per acre. This field was treated late in the maturity of the crop when practically all of the beans were already set and some dry beans, no longer favorable for insect attack were even present. A sample of 400 beans was examined at this time to determine the amount of insect injury at time of treatment.

Small Plot 2.—A small block 90 rows deep and 250 feet wide was treated with 5 per cent DDT-50 per cent sulfur on August 24, 1951 at approximately 35 pounds per acre. It was retreated on September 14 at approximately 32.7 pounds per acre. The remainder of the field was untreated. This field was in medium-early bloom and small pod stage at the time of the first treatment.

Small Plot 3.—Two small blocks each 61 rows wide were treated with a 5 per cent DDT-50 per cent sulfur dust. Plot A was 255 feet long and was separated from Plot B by an untreated check of about equal length. Plot B was 285 feet long. A county road separated these plots from an alfalfa field to the north. Both plots were treated on August 27, 1951 at approximately 32 pounds per acre and retreated on September 11, 1951 at approximately 37 pounds per acre.

At the time of first treatment the plants were about 18 inches high and just beginning to bloom and put out runners. There were just a few pods present 2 to 3 inches in length.

Small Plot 4.—A small block 90 rows deep and 225 feet wide was treated with 5 per cent DDT-50 per cent sulfur on August 27, 1951 at approximately 29 pounds per acre. It was retreated on September 12, 1951 at 30 pounds per acre. The remainder of the field remained untreated. At the time of treatment the plants were in medium bloom stage with a few full sized pods present. An alfalfa field was immediately adjacent on the south edge.

Some of the fields were double-cropped, with the beans following certain winter-growing vegetables, while others were single cropped. Most of the blackeyes were number 5 variety but some were 2's and 7's.

Lygus counts were made at approximately 7-day intervals by sweeping with a standard insect net.[3] Five sweeps were made across two rows at each station and a number of stations were swept in each field. For comparison purposes the results are reported as average numbers of lygus per sweep. The adults and nymphs of the two species involved are difficult to distinguish, especially under field conditions. As a consequence no attempt was made to segregate the species in the field when counts were made. This follows a precedent established by Smith and Michelbacher (1946) working with lygus bugs on seed alfalfa.

Laboratory examinations have shown that *Lygus hesperus* is the more common species. Stitt (1944) has indicated that this species causes more damage on alfalfa seed per individual insect than does *L. elisus* but the amount is not large. For practical purposes in estimating crop damage from known populations specific distinctions can be ignored.

No worm counts were made during the growth of the crop but certain observations were made on the small plots and their checks when sweeping for lygus.

Any defect, no matter how slight, which could be attributed to lygus or caterpillars was for our purposes considered to be injured. This is more severe than the inspection given the beans for U. S. standard grades. In this system usually one sting is not enough for a bean to be graded as damaged unless the sting is an especially large one or causes distortion of the bean. Sometimes two small stings, if they are on the same side of the bean and are small, are still allowed to pass as a clean bean.

All injury caused by lepidopterous caterpillars is classified as "worm injury" inasmuch as some pod borer damage on the dry bean is difficult to separate from the injury caused by other caterpillars.

OBSERVATIONS AND RESULTS.—Data given in table 1 show that lygus bugs were responsible for the major portion of the insect damage to blackeye bean seeds from all but one of twenty undusted fields examined. A lesser amount of damage was contributed by the lima bean pod borer, the corn earworm and the western yellow striped armyworm, and the cowpea weevil. Every untreated field examined showed seeds with typical necrotic lesions caused by the feeding of adult and

[3] Specifications for this net are available upon request from the Department of Entomology and Parasitology, Berkeley.

Table 1.—Total number of lygus and worm injured blackeye beans from a sample of 400 beans from each of 20 untreated fields. Stanislaus Co. 1951.

Lygus INJURED		WORM INJURED		BEANS INJURED	
No.	Per Cent	No.	Per Cent	No.	Per Cent
24	4.8	4	0.8	28	5.6
31	6.2	5	1.0	36	7.2
35	7.0	13	2.6	48	9.6
37	7.4	5	1.0	42	8.4
42	8.4	69	13.8	111	22.2
48	9.6	2	0.4	50	10.0
57	11.4	0	0.0	57	11.4
61	12.2	16	3.2	77	15.4
64	12.8	18	3.6	82	16.4
65	13.0	13	2.6	78	15.6
69	13.8	4	0.8	73	14.6
73	14.6	24	4.8	97	14.6
78	15.6	8	1.6	86	15.6
79	15.8	2	0.4	81	16.2
82	16.4	15	3.0	97	19.4
82	16.4	3	0.6	85	17.0
95	19.0	9	1.8	104	20.8
106	21.2	15	3.0	121	24.2
113	22.6	15	3.0	128	25.6
153	30.6	3	0.6	156	31.2

nymphal lygus. The amount of injury in the samples from different fields ranged from 4.8 per cent of the seeds damaged to 30.6 per cent. The average amount of seed damage for these samples was 14.1 per cent. The amount of caterpillar damage was considerably less, ranging from zero to 13.8 per cent. On the basis of lygus and caterpillar injury it is apparent that a majority of these fields would be severely down graded. As shown in table 1 the amount of worm injury was not too great with the exception of field number 5 which averaged 13.8 per cent of the seed damaged. An examination of the seed revealed that the lima bean pod borer was responsible for most of this damage.

The larva of the lima bean pod borer is the most destructive lepidopterous caterpillar that we have found feeding on blackeyes. It is very common and feeds entirely on the seed. Upon hatching from the egg, which is usually attached to the pod, the young larva quickly burrows through the pod and feeds within the developing bean. It may develop to maturity by feeding on one bean or by partially consuming a number of them. If conditions are not to its satisfaction it may leave the pod and enter another. We have encountered as many as three nearly mature larvae in one pod. An infested pod contains a characteristic mass of frass held together by a loose silken webbing (Fig. 3).

While it is possible to distinguish the injury caused to the seed by the lima bean pod borer if the characteristic pellets are present, these are sometimes absent, having been removed in the cleaning or harvesting process. It then becomes difficult or impossible in many cases to distinguish with any degree of certainty from that caused by other species of caterpillars.

The corn earworm has more of a tendency to feed upon the seed than does the western yellow striped armyworm which is more of a foliage feeder. Both of these species occur more or less commonly in most of the blackeye fields.

The injury caused to the blackeye seed by lygus feeding is quite typical and assumes several different appearances, depending upon such factors as stage of pod and seed development when attacked and the amount of feeding on any given seed. External symptoms of feeding on pods are normally lacking unless populations are extremely high. Pods growing immediately adjacent to an alfalfa field in the check adjacent to small plot number four showed numerous spots of lygus excrement and were smaller and somewhat discolored. Populations in this field were exceptionally high, averaging over three lygus per sweep in early September.

Injured seeds may not attain normal size or may be more or less distorted and shriveled. As pointed out by Baker, Snyder and Holland (1946), other factors beside lygus feeding may cause shriveling.

The typical injury in mature dry seeds is illustrated in Fig. 1A and varies from a slight swelling of the testa with an area of whitish granules in the cotyledon beneath to a large reddish brown necrotic area more or less filled with discolored, crumbly granules. An intermediate type of damage is shown in the second seed from the top in the right hand row of injured seeds. This appears as a bluish gray, somewhat raised circle on the testa. If the testa is removed at this point the characteristic white granules can be seen beneath. These granules stain bluish-black with iodine indicating the presence of starch.

Feeding spots may occur at any point on the seed, singly or in such numbers that coalescence and seed distortion re-

A B

FIG. 1-A.—Blackeye beans showing necrotic spots caused by the feeding of lygus bugs. B. Normal blackeyes.

sults. As noted by Baker *et al.* (1946) on lima beans, the testa may crack, starting from such feeding spots, and expose large areas of cotyledon.

Since lygus bugs are unable to feed on pods or seeds which have begun to toughen (Shull 1933), and since feeding will cause shedding of bloom and young pods, there is a relatively limited developmental period during which feeding will produce pitting of mature seeds. Blackeyes normally continue to bloom over a fairly long period, with one variety in particular, blooming almost until harvest. This means that blackeye beans subject to lygus attack are present over a long period of time.

The favorite host for *Lygus* spp. in California is alfalfa but appreciable numbers breed and reproduce on other crops such as lima beans and blackeyes. Eggs are frequently found inserted in the bean pod (Fig. 2) and on numerous occasions nymphs are more abundant than adults. When alfalfa fields are cut later in the summer many of the adult *Lygus* disseminate to adjacent fields. Unless the blackeye fields are nearing maturity, serious seed injury in the blackeye fields may result.

An excellent example illustrating the influence of an alfalfa field upon populations of lygus bugs in an adjacent blackeye field was presented in small plot 4. Samples of seed taken from the first 15 rows of blackeyes in the undusted part of the field immediately adjacent to the alfalfa showed an average of 39.4 per cent of the seed injured by lygus bugs. When samples were taken deeper in the field between rows 25 and 75, the lygus injury dropped to 17.5 per cent. These percentages are based on an examination of 800 seeds in each area.

Numerous workers (Smith & Michelbacher 1946, Russell & Barnes 1951) have demonstrated the efficacy of DDT and toxaphene against lygus bugs on alfalfa seed, so both of these materials were used by growers to treat the nineteen fields sampled. All of these fields were treated by airplane. The materials used on specific fields, number of applications and results obtained are tabulated in table 2. As can be seen in this table, lygus control as represented by the per cent of injured seed was good. Approximately two-thirds of the treated fields showed fewer injured seeds than the best untreated field. The average per cent of seed injury was 4.4 as compared to the aver-

FIG. 2.—Eggs of *Lygus* sp., inserted in pod of blackeye bean. Capitulum of eggs are flush with the surface of the pod. ×12.

FIG. 3.—Blackeye beans showing typical injury and webbed larval excrement of the lima bean pod borer, *Etiella zinckenella* (Treit.)

Table 2.—Results of treating nineteen fields of blackeye beans for control of *Lygus* and worms. Stanislaus Co., 1951.

Grower	Material Used	Number of Applications	*Lygus* Injured		Worm Injured		Beans Injured	
			Number	Per Cent	Number	Per Cent	Number	Per Cent
1	Toxaphene	2	2	0.4	5	1.0	7	1.4
2	DDT	1	4	0.8	24	4.8	28	5.6
3	Toxaphene	1	4	0.8	4	0.8	8	1.6
4	DDT	1	5	1.0	6	1.2	11	2.2
5	Toxaphene	1	6	1.2	8	1.6	14	2.8
6	DDT	1	7	1.4	2	0.4	9	1.8
7	Toxaphene	1	11	2.2	4	0.8	15	3.0
8	Toxaphene	1	13	2.6	12	2.4	25	5.0
9	Toxaphene	2	14	2.8	23	4.6	37	7.4
10	Toxaphene	1	16	3.2	5	1.0	21	4.2
11	DDT	1	20	4.0	1	0.2	21	4.2
12	Toxaphene	1	21	4.2	4	0.8	25	5.0
13	Toxaphene	1	25	5.0	6	1.2	31	6.2
14	Toxaphene	1	31	6.2	3	0.6	34	6.8
15	DDT	1	31	6.2	14	2.8	45	9.0
16	DDT	1	44	8.8	2	0.4	46	9.2
17	DDT	1	45	9.0	17	3.4	62	12.4
18	DDT	1	45	9.0	10	2.0	55	11.0
19	Toxaphene	1	75	15.0	22	4.4	97	19.4

age of 14.1 per cent for untreated fields.

Several of the grower-treated fields showed unexpectedly high counts of injured seed. Some of these fields were located in the southern and eastern part of Stanislaus County where lygus injury was particularly severe as shown by adjacent undusted fields. In addition, some fields were earlier than others and some were treated several weeks after the first pods were set.

Control of caterpillars as shown in table 2 does not appear too good but under the circumstances was probably as good as could be expected. Undoubtedly the primary reason for the lack of better control was the fact that larvae of the pod-borer are not killed by DDT or toxaphene. As a result the per cent injury due to worms in many cases indicates the relative abundance of pod borer larvae. This is not always true since a poor application or one not timed properly would permit larvae of the corn earworm and yellow striped armyworm to escape.

Results from the small hand treated plots are presented in table 3. These data show that untreated plots had lygus injured seed in all samples, as did all the samples from the untreated survey fields. They varied from a low of 9.6 per cent to a high of 28.3 per cent of the seeds in-

Table 3.—Blackeye beans from treated and untreated small plots showing lygus counts, seed sample size and per cent of lygus and worm damage.

Grower	Treatment	Average *Lygus* per Sweep					Seeds Examined	*Lygus* Injured	Worm Injured
		Aug. 27	September						
			5	13	19	26			
1	Check			1.24	2.14		800	9.6	2.4
	DDT			0.72	0.16		500	1.0	0.0
2	Check		0.59	1.26	1.12		500	12.4	0.2
	DDT		0.08	0.11	0.00		500	0.8	0.0
3	Check	0.18[1]	0.24	0.57	1.66	2.51	1000	15.3	1.1
	DDT	0.18[1]	0.09	0.07	0.07	0.07	1000	0.7	0.5
4	Check	0.84[1]	1.16	1.78	3.38		1600	28.3	1.1
	DDT	0.84[1]	0.08	0.06	0.78		1600	5.4	0.6

[1] Pre-treatment counts.

jured by lygus feeding. In the corresponding DDT treated plots the injury was considerably reduced and ranged from 0.7 per cent to 5.4 per cent.

Small plot number four was receiving a constant influx of lygus adults from an adjacent heavily infested alfalfa field. The amount of lygus injury showed a direct correlation with the distance from the alfalfa field. A sample taken in the treated plot from rows 1–15 adjacent to the alfalfa showed 10.8 per cent of the seed with lygus bug injury. However, when a similar sample was taken from rows 25–75 the amount of damage had dropped to 0.08 per cent. These two samples were averaged to give 5.4 per cent lygus injured seed in the treated plot. Similar sampling technique in the adjacent check showed 39.4 per cent injury adjacent to alfalfa and 17.5 per cent injury deep in the plot.

Lygus control was excellent in all of the hand treated plots. Only one nymph was ever found on post treatment surveys. A few adults were found in most of the treated plots, but it is difficult to say whether they were unaffected by the DDT or were recent migrants from adjacent fields. The excellent lygus kill is reflected in the protection afforded the treated blackeyes.

Worms did not appear to be much of a problem in the small plots. DDT gave control in all cases. Surveys indicated that the corn earworm was the principal caterpillar present and DDT is effective against this species.

The cowpea weevil, *Callosobruchus maculatus* (F.) was encountered several times while sweeping for lygus and at harvest time five lots from untreated fields were found to be infested. Survey field number eight which was dusted with 10 per cent toxaphene was the only treated field showing weevil infestation at harvest time.

DISCUSSION.—From these data as well as from reports from bean buyers and warehousemen it is evident that lesions caused by lygus as a result of their feeding are probably the main factor in determining blackeye bean quality in the San Joaquin Valley.

These data also tend to show that no appreciable damage occurred to blackeyes where the population of lygus bugs remained approxiamtely 0.1 to 0.2 individuals per sweep. When the population approached an average of 1 or more per sweep, especially if this occurred early in the maturity of the crop, considerable damage resulted in most cases. Migrating adults to and from the blackeye field can cause large and rapid fluctuations in a population. It is conceivable that a flight of adults could come from an adjacent cut alfalfa field into a less desirable crop such as blackeyes, cause considerable damage and leave before surveys could detect the influx. Other investigators (Shull 1933) attempting to correlate amount of damage to lima and other bean seeds with lygus populations have had little success in doing so.

An application of 5 per cent DDT or 10 per cent toxaphene applied in the early pod stage when lygus bugs are present in numbers will in most cases result in a marked improvement in seed quality. Neither of the above will give satisfactory control of the larvae of the lima bean pod borer. Either material will, however, give satisfactory control of both the corn earworm and western yellow-striped armyworms. At the present time it appears that one correctly timed and applied dusting will give adequate control of lygus and several species of caterpillars. It also appears that the cowpea weevil is also controlled by the materials mentioned.

SUMMARY.—Nineteen treated and 20 untreated fields of blackeye beans were surveyed for insect damage in Stanislaus County in the San Joaquin Valley during 1951. The treated fields received either 5 per cent DDT or 10 per cent toxaphene applied by airplane. In addition to these surveys, small plots of approximately one acre in size located in undusted fields were treated by means of rotary hand dusters with a 5 per cent DDT-50 per cent sulphur dust.

It was found that lygus bugs were responsible for the major portion of insect damage found on the beans at harvest. Every sample examined that came from an undusted field showed seed with typical necrotic lesions caused by the feeding of lygus bugs. The amount of injury varied between fields from 4.8 per cent to 30.6 per cent of the seeds with blemishes. The average untreated field had 14.1 per cent of the beans damaged. Two species of lygus are involved in causing this feeding injury, *Lygus hesperus* Knight and *L.*

elisus Van Duzee. Lygus bugs prefer to feed and breed in alfalfa fields but appreciable numbers complete their life cycle in blackeye bean fields. These numbers are augmented by migrating adults from nearby alfalfa fields which are cut or drying. Samples of beans taken at varying distances from a lygus infested alfalfa field showed a direct correlation between amount of seed injury and proximity to the alfalfa.

Lygus damage was considerably reduced in a number of fields treated with DDT or toxaphene. The amount of injured seed from these fields ranged from 0.4 per cent to 15 per cent with an average of 4.4 per cent.

All of the samples from the checks adjacent to the small treated plots showed lygus injury which varied from 9.6 per cent to 28.3 per cent. Treatments with DDT-sulphur to adjacent one acre plots gave excellent control of lygus and reduced the amount of seed damage considerably. The samples from these treated plots varied from 0.7 per cent to 5.4 per cent.

In addition to the injury caused by lygus bugs, a certain amount was contributed by the feeding of various species of lepidopterous caterpillars on the developing seed. The corn earworm, *Heliothis armigera* (Hbn.); the lima bean pod-borer, *Etiella zinckenella* (Treit.), and the western yellow-striped armyworm, *Prodenia praefica* Grote are the three most important species involved. The lima bean pod-borer is not controlled by either DDT or toxaphene and when it is the most abundant species of caterpillar present in a field, poor worm control can be expected. Blackeyes are a favored food of the pod borer and on occasions this caterpillar can do serious damage to a field. Seed samples indicated that the pod borer was responsible for most of the worm damage recorded from the large fields surveyed. Samples from these fields showed that untreated fields averaged 2.5 per cent seed injury due to worms while the treated fields averaged 1.8 per cent. This is undoubtedly a reflection of the poor control of this caterpillar with DDT or toxaphene. Better worm control was secured in the small plot treatments with DDT-sulphur, but field surveys here indicated that the corn earworm and not the pod-borer was more common.

Field treatments with DDT or toxaphene also gave some control of the cowpea weevil, *Callosobruchus maculatus* (F.). Five untreated lots were infested at harvest while only one of the treated plots showed an infestations.

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A Mosquito Survey and Control Program in Guam

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During the Marianas Islands Campaign of World War II, American forces on the islands of Saipan, Tinian, and Guam experienced severe epidemics of dengue fever. On Guam there were more than two thousand reported cases. This paper is concerned only with the latter island.

The severity of the epidemic declined as the percentage of immune personnel increased and the rainy season ended. In order to forestall another epidemic which would be fostered by the constant arrival of large numbers of non-immunes and the onset of the next rainy season, the authors, then attached to U. S. Naval Medical Research Unit No. 2, were assigned the task in January, 1945 of gathering basic epidemiological data leading to preventive measures. A survey of the mosquito population and small scale control experiments led to a report (unpublished) in March, 1945 to Island Command (Guam, M. I.) with control recommendations. The senior author was then transferred to this Island Command and took charge of the organization and carrying out of the control.[3] Operations began the same month and involved some unique control procedures which apparently resulted in the complete elimination of the presumed vector, *Aëdes aegypti*, from the island (Reeves, 1948).

Preliminary Survey.—A preliminary survey of the island for mosquito breeding was conducted from January 27 to February 28, 1945. The primary objectives were military camps and areas occupied by natives, and travel of necessity was confined to usable roads. However, all parts of the island were visited except a few remote and restricted areas in which combat patrols were operating.

The five species reported from Guam previous to 1945 (Swezy, 1942) were *A. aegypti* (Linnaeus), *A. pseudoscutellaris* (Theobald),[4] *A. pandani* Stone, *A. oakleyi* Stone, and *Culex quinquefasciatus* Say. All of these except *A. oakleyi* were found commonly during the preliminary survey. In addition *A. vexans nocturnus* (Theobald) and *C. annulirostris mariannae* Bohart & Ingram (1946) were collected. Surveys later in 1945 uncovered *A. oakleyi* as well as two additional species, *C. sitiens* Wiedemann and *C. litoralis* Bohart (1946), bringing the total to nine species.

Species Habitat Preferences.—The Guam mosquitoes can be divided for practical purposes on the basis of their habitat preferences. Thus artificial containers usually harbored *Culex quinquefasciatus* and frequently *Aëdes aegypti* near hatitations or *A. guamensis* farther away from living quarters. Presence of other species in artificial containers was exceptional. Similarly, freshwater ground pools usually contained *C. quinquefasciatus*, and occasionally *C. annulirostris mariannae*. During the rainy season *A. vexans nocturnus* appeared in such pools. Brackish rock pools contained one or both of *A. litoralis* and *A. sitiens*. Tree holes frequently contained *A. guamensis* and rarely (near habitations) *A. aegypti*. *Pandanus* leaf axils were specific locations for larvae of *A. pandani*.

Many hundreds of larval collections were made but the 115 collections taken during the preliminary survey were representative. These were made from inhabited areas and adults were reared to confirm the identifications. *Culex quinquefasciatus* occurred in 80.8 per cent of the collections, *Aëdes aegypti* in 49.6 per cent, *A. guamensis* in 8.7 per cent, *C. annulirostris mariannae* in 7.0 per cent, and *A. vexans nocturnus* in 0.9 per cent. Two or more species were found in some of the collections. *A. pandani* was not included although it occurred commonly in *Pandanus* thickets near habitations early in 1945. Subsequent clearing operations for military reasons reduced the breeding areas of this species.

Of the 57 collections of *Aëdes aegypti* in the preliminary survey, 44 were from metal drums, 11 from miscellaneous containers such as crocks, tins, and tires, and 2

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[3] The authors were materially aided in the preliminary phases of the work by H. E. Cott. Later, George S. Hensill, then Lt. Cdr., H(S), USNR, and other personnel under his direction became a major part of the organization. We wish to acknowledge the efforts and suggestions of these individuals and all other parties who helped in this project.

[4] This was a misidentification and the species was later named *guamensis* by Farner & Bohart (1945).

from tree holes. All of these were in close proximity to human habitations, either occupied or recently so. With respect to deserted native huts our observations lead us to believe that, after abandonment, the *A. aegypti* infestations quickly dissipated as the adults emerged. Also, natives moving to a new domicile took with them containers infested with *A. aegypti* eggs or larvae. In fact, the distribution of this species could be accounted for mainly by a spread in this fashion, and the absence of *A. aegypti* in the isolated villages of Umatac, Merizo, Inarajan, and Yigo could be laid to poor transportation facilities. A map outlining the distribution of *A. aegypti*, published by Bohart & Ingram (1946), emphasized the concentration of *A. aegypti* breeding along the west coast and throughout the agricultural areas in a wide band across the middle of the island.

Of unusual interest in the light of later developments was the absence of *Aëdes albopictus* (Skuse) and *Anopheles subpictus* (Grassi), both of which were discovered in 1948 according to Reeves (1948) and Bryan (1949).

EPIDEMIOLOGY OF DENGUE FEVER ON GUAM, 1944–45.—Early reports of public health conditions on Guam state that dengue fever epidemics occurred there in 1911, 1932, and 1937. As collections of mosquitoes made from Guam do not record *Aëdes aegypti* from this island before 1936, it must be inferred on the basis of epidemiological evidence that the vector was present but overlooked by entomologists.

During World War II, "D" day on Guam was July 21, 1944, and the island was declared secure on August 10. Incomplete records on the cases of dengue during August are understandable as no semi-permanent camps were established. Natives stated that the Japanese during their 31 month occupation of the island made practically no attempt to control sanitary conditions and, specifically, practiced no mosquito control. A high mosquito population, therefore, was present at the time of its recapture. This condition, together with the disruption of normal life and the introduction of many thousands of non-immune servicemen, coincided with the beginning of the rainy season. As could be expected, an epidemic resulted. From interviews we ascertained that the largest number of cases were contracted in the west-central portion of the island from Agana to Agat, where the landings were made. In this area also was the greatest concentration of personnel and abandoned wreckage. These facts agree with Usinger's (1944) observation in the Honolulu outbreak that the incidence of cases is correlated with density of human population.

From incomplete records, Table 1 was compiled.

Table 1.—Incidence of dengue fever among personnel on Guam, September, 1944 to February, 1945, compiled from Island Command sick report files.

Month	Total No. Cases All Units	Total Units Reporting	Total Units Having Dengue
September, 1944	1684	29	28
October	469	30	27
November	168	39	28
December	73	48	16
January, 1945	84	56	25
February	25	52	9

It is worthy of note that during December through February over half of the total number of cases reported were in Army units, most of which were new arrivals.

In contrast, Table 2 presents as complete a record as could be assembled by the Military Government Medical Staff on the cases among the natives.

It can be seen from the above records that the disease was reduced to a very low level by the summer of 1945. This condition was the result of three principal factors; the mosquito control efforts, the larger percentage of immunes then in residence, and the dry season. To our knowledge no outbreak of dengue fever has occurred on this island since the war.

CONTROL.—Following the completion of the survey, which clearly showed *Aëdes aegypti* to be the only likely vector of dengue, plans to initiate a species control program were made. Naturally, certain limitations were encountered concerning equipment and insecticides. Experimental data were necessary on the most effective, economical method of applying the then new material, DDT, in the available formulations.[5]

[5] The DDT formulations available were as follows: (1) DDT-xylene emulsion containing 20 per cent DDT, 60 per cent xylene, and 20 per cent Triton X-100 by weight; (2) DDT, technical, approximately 75 per cent para-para' isomer; (3) DDT-Velsicol NR-70 emulsion, 35 per cent DDT.

Table 2.—Partial record of new dengue fever cases among the native population on Guam.

1944		1945	
Weekly period	No. of Cases	Weekly Period	No. of Cases
Oct. 1– 7	?	Dec. 31–Jan. 6	0
8–14	4	Jan. 7–13	0
15–21	5	14–20	0
22–28	8	21–27	2
29–Nov. 4	6	28–Feb. 3	?
Nov. 5–11	4	Feb. 4–10	0
12–18	51	11–17	0
19–25	6	18–24	0
26–Dec. 2	4	25–Mch. 3	5[1]
Dec. 3– 9	2	Mch. 4–31	0
10–16	0	Apr. 1–28	0
17–23	1	Apr. 29–May 6	1
24–30	4	May 7–31	0
		June 1–30	0
		July 1–29	0

[1] Diagnosis not made by a physician.

In the light of the biological and ecological facts learned from the survey, it was apparent that the control program should follow two distinct lines, (1) permanent control of unnecessary breeding places and prevention of the creation of new ones and (2) continuing control (treatment) of other breeding places together with continual inspection of them. The latter class involved rain-water barrels, wash buckets, miscellaneous wash racks and necessary containers in the immediate environment of the homes, which could not be eliminated.

Permanent control measures included elimination of debris created by the bombing of the inhabited areas, particularly the city of Agana and nearby communities on the west-central portion of the island. Secondly, the elimination of breeding in military camps and supply dumps containing items such as shell casings and spare parts, tarps, stacked crated goods, truck beds of wrecked vehicles, etc. Lastly, elimination of tree-hole breeding (by filling with dirt) and tin can and refuse dumps adjacent to native homes.

The problem of controlling mosquito breeding in the innumerable rain barrels (oil drums) and other water-gathering containers on a tropical island can be fully appreciated only by those who have tried to do it. Also, the situation was made even more difficult by the presence of the disrupted and migrant population following the recapture of Guam.

Since the so-called domesticated mosquito, *Aëdes aegypti*, was primarily involved, it was apparent that the immediate vicinity of farm dwellings, villages, camps and towns would be the center of attack. The survey had already provided the following indications of the preferred breeding places: (1) no larval infestations were found farther than 75 feet from human habitations, (2) rainwater, partially shaded and free of road-dust was preferred, (3) in order of choice the breeding containers were: wooden buckets and and bamboo sections, crockery (including flower containers), clean oil drums with one end removed, and discarded tires. Of these, the oil drums were the most numerous and could not be eliminated. Therefore, experimental work was begun in native villages which appeared to be the foci of the disease.

To control breeding in barrels it was decided to use covers, some of which would be treated with DDT. In several native villages each rainwater barrel was numbered and the cover given a corresponding number. The covers were of four types, burlap, unbleached muslin, cheesecloth (double thickness) and scrap lumber (one-half to three-fourths inch thick). The muslin and cheesecloth were soon abandoned since the natives would not replace them each time after using water from the barrel, they became easily torn, and when wet would sag and fall into the barrels. Furthermore, they were appropriated for diapers, window curtains, and bandages, The wooden covers, if kept tightly over the barrels, prevented egg-laying and reduced the infes-

Table 3.—Summary of mosquito control operations, Guam, 1945.

	Feb.	March	April	May	June	July	Aug.	Sept.	Totals
Man hours worked		11,988	11,374	11,752	11,881	9,396	10,226	7,356	73,973
Native houses inspected	548	914	1,409	1,735	2,137	2,160	964	1,511	11,378
Native buildings and ranches worked by control crews		no record	no record	1,155	4,512	5,618	5,105	3,369	19,759
Water barrels and other potential breeding places found by inspectors	1,488	2,315	3,710	2,522	2,224	2,668	1,129	2,879	18,935
Containers sprayed or eliminated by control crews		no record	no record	4,062	7,941	9,337	9,537	6,653	37,530
Ae. aegypti infestations: found by inspectors	294	200	127	34	12	13	3	1	684
Inspections of military units	28	no record	36	52	50	68	76	84	394
Military units reporting mosquito breeding of all types		7	no record	8	12	19	10	9	65
Ae. aegypti infestations in military units	19	no record	5	2	2	2	1	1	32
Ae. aegypti breeding index, per cent	19.7	8.6	3.4	1.8	0.53	0.48	0.26	0.034	
Materials expended on *Ae. aegypti* control		no record	no record						
DDT, technical, formulation #2				0	0	0	1,180	200	1,380 lb.
DDT-xylene emulsion, formulation #1		7.5	9	9	5	4	8	6	48.5 gal.
DDT-treated burlap barrel covers	111	3,220	3,215	1,944	1,400	1,149	1,965	230	13,234
Diesel Oil		440	715	825	1,550	3,925	4,990	1,870	14,315 gal.

tation, but proved to be cumbersome. They were often left askew, on the ground, or were found to be too heavy for children and women to lift and replace with one hand while dipping water with the other. Tin and wire screen covers were unsatisfactory. Burlap proved to be the most practical as it was serviceable and had sufficient weight to stay in place without a supporting frame. A thirty-inch square was the average size employed and the material was obtained from salvaged sacks or any other source available.

The squares to be treated were laid atop one another in a pile and approximately the center two-thirds of the one on top was painted with the five per cent DDT-xylene emulsion (Formulation #1)[5] using a 3 or 4 inch paint brush. The excess amount that soaked through was absorbed by the layers below, thereby conserving as much material as possible. Each treated square was then stacked on another pile. After drying, they were rolled up in bundles and distributed in the control zones.

One gallon of the 5 per cent DDT emulsion treated 60 squares. Records were kept of the first forty treated burlap covers which were all placed in one small village. The majority remained effective with the one treatment for three months, and when water was poured through the burlap, after three months, the larvae added to the test water were all dead in twenty-four hours. A few individual covers remained in use for five months, the others having rotted.

It should be noted that rain soaking through the covers carried minute amounts of DDT into the barrels, and in dry periods the mechanical action of removing and replacing the burlap over the barrels dislodged enough impregnated fibers to keep the DDT content of the water at a lethal level for the larvae.

After the experimental work with barrel covers was completed, a revised island-wide control program was instituted, and

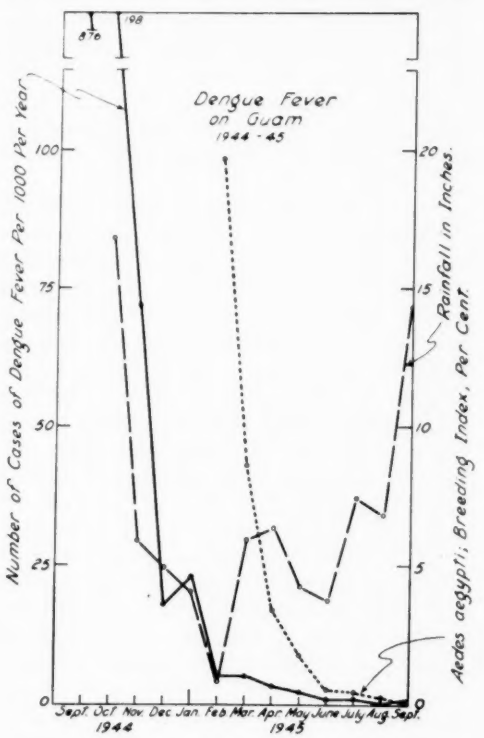

FIG. 1.—Comparison of rainfall, dengue fever incidence and *Aëdes aegypti* index for the year starting September, 1944.

five zones were established. Natives, varying in numbers from 30 to 50, were divided into five work crews, each supervised by naval personnel. Each crew had hand tools, treated burlap, knap-sack sprayers and flit guns. Refuse piles with potential breeding containers were sprayed with diesel oil, burned or buried. Tree holes were filled with soil. Scrap lumber and firewood piles were stacked off the ground. Water barrels were covered with treated burlap and any in excess of domestic needs were overturned and perforated. Water-holding containers for chickens and livestock were emptied and sprayed if found infested. Daily records of the work accomplished and materials expended were kept and summarized monthly (Table 3). However, in the organizational period of March and early April incomplete records only were available.

As the control work progressed a number of facts became apparent. During the rainy season all areas had to be reworked by the control crews every two weeks and the inspectors had to follow up continually. The living habits of the natives were such that it was almost impossible to reduce the number of potential breeding places constantly being created (compare data for March and September in table 3). As the water barrels and other containers were eliminated, protected by DDT residue, or sprayed with oil, the larvae had few places left in which to survive. As a result they were found more frequently indoors, particularly in vases, cans, jars, and bamboo sections used for flower and bulb containers.

The educational program, through the schools and the district native commissioners, proved to be also a continuing and necessary phase of the program. In order to obtain necessary cooperation a method of fines for violations of the Sanitation Order was established and enforced by Military Government. Information circulars, posters and sanitation directives were distributed through the native newspaper and on village bulletin boards.

Mosquito breeding in military camps was held to a minimum and local control was enforced by the sanitation officer of each unit under an Island Sanitation Order. However, under the conditions it was impossible to obtain 100 per cent control.

As the natives moved about frequently, often transporting empty water barrels, inspections were made of containers when found in transit. *Aëdes aegypti* larvae were found in minute amounts of water still remaining inside the rim at the bottom of barrels (or drums) and in wooden wash buckets. Therefore, it was definitely proven that larvae of this mosquito were spread by artificial means. Obviously the egg stage could be similarly transported.

PEST MOSQUITO CONTROL.—The many complaints from military units made it necessary to supplement the dengue vector control with pest mosquito control methods. There were three principal species involved, each with distinctly different habits as pointed out above.

Probably the easiest species to control was *Aëdes vexans nocturnus*. Airplane applications of 5 per cent DDT-Velsicol in diesel oil to the shallow freshwater ponds created by the increasingly heavy rains in July and August gave an excellent kill. In addition, spraying of the breeding areas before a heavy rain with the same mixture, using a decontamination power sprayer, left sufficient residue on the soil, grass, and shrubs to kill the newly-hatched larvae after the area was flooded and inaccessible to ground rigs. Control of this mosquito in known breeding areas gave much appreciated relief to adjacent camps.

The common *Culex quinquefasciatus*, which was found commonly in polluted water run-off from wash-racks and cooking and bathing areas in and about native habitations, was controlled by basic sanitation methods. Since this was a year-around pest, continual inspection and elimination of the breeding areas proved to be the only practical procedure. DDT sprays were usually not too effective because of the pollution and continual addition of new wastes. This mosquito was not a pest in military camps since regular sanitation inspections kept military units continually aware of their obligation to provide drainage, soakage pits, and treatment or coverage of open water surfaces.

The most difficult of the pest mosquitoes to control, *Aëdes pandani*, was also the most severe biter. This mosquito was a problem only in camps and living areas surrounded by or near heavily wooded areas in which *Pandanus* was prevalent. This "host" plant was practically

impossible to spray from the ground. The water standing in the crown of an individual plant was rarely more than a half cupful but made treatment of the entire area by plane necessary. During the rainy season the water in the plants never entirely dried up, and frequent plane applications were necessary to give relief in jungle areas.

Tests showed that only 7 to 10 days maximum protection from adults was given from one plane (C-47) application of the 5 per cent DDT-Velsicol in diesel oil at the rate of 0.4 lbs. of DDT per acre. Heavy rains flushed out the residue and insufficient toxicant remained to kill continually hatching larvae. Water samples collected 3 days later from the plants in treated areas contained residue insufficient to kill larvae in laboratory tests.

Materials expended by plane in the pest mosquito control work, June through September, were as follows: diesel oil, 21,925 gal.; kerosene, 17,610 gal.; Velsicol NR-70, 6,375 gal.; DDT (tech., formulation #2), 20,610 lbs., or a total of 45,800 gals. of 5 per cent DDT solution. A total of 92 flights were made in applying this solution.

SUMMARY.—Several objectives were accomplished by the mosquito survey and control program on Guam in 1945. The knowledge of the species was expanded and the distribution and habits of the presumed disease vector under central-Pacific island conditions were worked out. Original methods for controlling *Aëdes aegypti*, particularly with DDT-treated cloth covers, were devised. Rain soaking through the covers carried minute amounts of DDT into the barrels, and in dry periods the mechanical action of removing and replacing the covers dislodged enough impregnated fibers to keep the DDT content of the water at a lethal level for the larvae. Previously known principles of species sanitation and the necessity of continual inspection were reaffirmed. Dengue fever was reduced to the vanishing point (Fig. 1) and according to later findings, *A. aegypti* was apparently eliminated from the island.

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Parathion, DDT and EPN Deposits on Peach Foliage and Fruit

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The loss of insecticide residues from peach foliage and immature fruit and the amount of residue on fruit at harvest are of considerable importance in the control of the oriental fruit moth, *Grapholitha molesta* (Busck). In 1950 and 1951 studies were made of the loss of parathion, DDT, and EPN residues from peach foliage and immature fruit, the residue on fruit at harvest, and the effectiveness of these insecticides in different spray schedules to control the oriental fruit moth. These studies were a continuation of the studies made in 1948 (Brunson & Koblitsky 1950) and were made on the varieties Summercrest and Elberta in commercial orchards within a 12-mile radius of Moorestown, New Jersey. The owners of the orchards applied the usual lead arsenate sprays for plum curculio, *Conotrachelus nenuphar* (Hbst.), and sulfur sprays or dust for brown rot control.

Applications of insecticides to reduce oriental fruit moth injury to fruit are usually directed against second- and third-brood larvae. In the vicinity of Moorestown second-brood larvae begin to appear in orchards about June 20 and third-brood larvae about July 20. The applications are generally started about July 10, when second-brood larvae are abundant in twigs and scarce in fruits.

Previous Studies.—Brunson & Koblitsky (1950) showed that in New Jersey about 70 per cent of the initial deposit of DDT on peach leaves was lost during the first week after application and that the residue decreased very little during the next 2 weeks.

Barnes *et al.* (1950) showed that in California DDT residues on peach fruits from 1 pound of 50 per cent wettable powder per 100 gallons were 16.1, 7.6, 4.4, and 2.7 p.p.m. and parathion residues from 1 pound of 25 per cent wettable powder per 100 gallons were 4.5, 1.5, 1.0, and 0.2 p.p.m. after 0, 7, 14, and 30 days, respectively.

Fahey *et al.* (1951) showed that in northern Ohio parathion residues on peach fruits from 2 pounds of 15 per cent wettable powder per 100 gallons were 4.3, 1.6, 0.8, and 0.2 p.p.m. after 0, 8, 15, and 29 days; and in southern Indiana parathion residues from 1.5 pounds of 15 per cent wettable powder per 100 gallons were 3.03, 0.19, 0.17, and 0.04 p.p.m. after 0, 7, 14, and 27 days. EPN residues on peach fruits from 1 pound of 25 per cent wettable powder per 100 gallons were, respectively, 8.3, 5.6, 2.9, and 1.5 p.p.m. after 0, 8, 15, and 29 days in northern Ohio, and 2.05, 0.38, 0.40 and 0.14 p.p.m. after 0, 7, 14, and 27 days in southern Indiana.

Walker (1950) reported that in Washington parathion residues on peach fruits at harvest were 1.63 and 0.80 p.p.m. 7 and 30 days after application.

Materials and Methods.—The amounts of insecticides used per 100 gallons of spray were as follows: Parathion, 2 pounds of 15 per cent wettable powder; DDT, 2 pounds of 50 per cent wettable powder in 1950 and 1.5 pounds of 75 per cent wettable powder in 1951; and EPN, 1.5 pounds of 25 per cent wettable powder. Sprays were applied with a conventional power sprayer at 400 pounds pump pressure, and a hand spray gun fitted with a No. 6 orifice disk in 1950 and No. 7 orifice disk in 1951.

Schedules were as follows: Three applications of parathion at 2-week intervals with the last application 2 weeks before harvest; two applications of parathion at 3-week intervals with the last spray 3 weeks before harvest; parathion 6 weeks before harvest and DDT 3 weeks before harvest; DDT 6 weeks before harvest and parathion 3 weeks before harvest; and two applications of EPN at 3-week intervals with the last application 3 weeks before harvest. The dates that sprays were applied were based on August 21, the average harvest date of Summercrest in the vicinity of Moorestown. The number of days between applications and between the last application and harvest varied in some cases a day or more from the planned schedule owing to unfavor-

[1] E. L. Plasket assisted in the field work and R. W. Coles and J. J. Lockowitz assisted in the chemical analyses.

able weather and to fruit ripening before or after the average ripening date.

The four schedules were replicated in three orchards each year. The sprays of each schedule were applied to 10 single-tree plots, which were randomized in blocks of Summercrest or Elberta trees. There were also 10 randomixed single-tree control plots in each experimental block of trees. The plots were separated from adjacent plots by one unsprayed tree.

Leaf samples for residue determinations were taken in duplicate from each experimental and control series of plots immediately after each application of spray had dried and weekly thereafter for 2 or 3 weeks depending on the scheduled intervals between applications. Each sample was a composite of 50 leaves, 5 leaves taken at random, within reach of the ground, from each of 10 plots. Immediately after the leaves had been removed from the trees, they were placed in a pint fruit jar covered by a loosely fitted lid. The number of samples for parathion on each sampling date ranged from 27 to 33 except after 3 weeks, when there were 12 each year. With the DDT samples there were 6 to 15 on each date in 1950 and 6 in 1951. With EPN there were 11 or 12 on each date. The variation in the samples was about normal.

In 1951 fruit samples for residue determinations were taken in duplicate at the same time that leaf samples were taken. The numbers of samples at the different sampling dates were: Parathion, 10 to 26; DDT, 4 to 6; EPN, 10 to 12. In 1950 fruit samples were taken in triplicate at harvest-time only. Each sample consisted of 25 fruits taken at random, 2 fruits from the even and 3 from the odd-numbered plots. The fruits were picked directly into large, heavy paper, shopping bags.

Fruit samples for determinations of oriental fruit moth injury were taken from each experimental and control plot when the fruits were ripe and ready for harvest. Each sample consisted of 200 fruits, 20 fruits selected at random from each plot. The fruits from each plot were kept separate in small baskets. Each fruit was dissected and was considered injured if larvae or signs of larval feeding were found.

The total-chlorine method used for the determination of DDT residue on leaf and on fruit samples was the same as given previously by the authors (1950). The magenta color reaction of Averell & Norris (1948) was used for parathion residue analysis. A slight modification of this method was used for EPN analysis (Anonymous 1951). The residue on leaf samples was expressed as micrograms per square centimeter of leaf, and on fruit as micrograms per fruit and parts per million.

RESIDUE ON LEAVES AND IMMATURE FRUIT.—A summary of the residues on leaves and fruit immediately following spray applications and weekly thereafter for 3 weeks is shown in tables 1 and 2. The percentages of loss of residues are in reference to the original deposit. The rate of parathion residue loss from both leaves and immature fruit was greater than the loss of EPN; DDT was lost at the lowest rate. The difference in the rate of DDT loss between the 2 years was probably due to a difference in the insecticide formulation, as the spray concentration and methods used were the same in both years. The rate of DDT loss from leaves reported by Brunson & Koblitsky (1950) was about the same as the rate of loss observed in these studies in 1950.

Parathion and EPN residues were lost at a considerably greater rate from leaves than from fruit. DDT residue was lost from leaves and fruit at about the same rate. The values from fruit are in very close agreement with those reported by Barnes *et al.* (1950) and Fahey *et al.* (1951) for northern Ohio, but less than those reported by Fahey for southern Indiana. The progressive average losses of DDT residue from fruit were about 40 per cent less than those reported by Barnes. The progressive average loss of EPN residue from fruit agreed closely with Fahey's results.

RESIDUE ON RIPE FRUIT.—The amounts of insecticide residue on ripe fruit are shown in tables 3 and 4. The data presented in table 3 combine the results from the experiments discussed throughout this paper and additional results from three spray schedules replicated in six orchards in 1950 and from four spray schedules replicated in three orchards in 1951. The additional results were from related experiments in which the amount of insecticides in sprays and the methods used were the same as described in this paper.

Table 1.—Parathion, DDT, and EPN residues on peach leaves at weekly intervals following spray applications.

PERIOD FROM SPRAYING TO SAMPLING	PARATHION		DDT		EPN	
	Residue	Loss	Residue	Loss	Residue	Loss
weeks	μg./cm.²	per cent	μg./cm.²	per cent	μg./cm.²	per cent
1950						
0	1.37	—	8.2	—	—	—
1	0.10	92.7	2.5	69.5	—	—
2	0.02	98.5	2.0	75.6	—	—
3	0.00	100.0	1.2	85.4	—	—
1951						
0	1.94	—	11.4	—	2.74	—
1	0.10	94.8	7.7	32.6	0.47	82.8
2	0.02	99.0	6.2	45.8	0.23	91.6
3	0.01	99.5	5.4	52.8	0.09	96.7

Table 2.—Parathion, DDT, and EPN residues on immature peach fruits at weekly intervals following spray applications in 1951.

PERIOD FROM SPRAYING TO SAMPLING	PARATHION		DDT		EPN	
	Residue	Loss	Residue	Loss	Residue	Loss
weeks	μg./fruit	per cent	μg./fruit	per cent	μg./fruit	per cent
0	146.8	—	943.8	—	155.5	—
1	49.1	66.6	645.1	31.6	69.2	55.5
2	22.9	84.4	555.2	41.1	44.5	71.4
3	5.9	96.0	463.1	50.9	28.4	81.7

Table 3.—Parathion, DDT, and EPN residues on ripe peaches.

PERIOD BETWEEN LAST SPRAY AND SAMPLING	PARATHION			DDT			EPN		
	Samples	Average	Maximum	Samples	Average	Maximum	Samples	Average	Maximum
days	number	p.p.m.	p.p.m.	number	p.p.m.	p.p.m.	number	p.p.m.	p.p.m.
1950									
11	3	0.44	0.48	—	—	—			
14	3	0.28	0.33	—	—	—			
15	3	0.31	0.35	—	—	—			
16	5	0.12	0.13	3	6.1	6.6			
17	6	0.05	0.07	3	6.5	6.9			
Average		0.20	—	—	6.3	—			
18	6	0.08	0.10	3	5.3	5.8			
19	6	0.08	0.10	3	5.8	6.3			
20	6	0.08	0.11	3	5.7	5.9			
21	6	0.09	0.11	3	5.3	5.8			
22	17	0.10	0.15	6	4.8	6.7			
Average		0.09	—	—	5.3	—			
1951									
7	2	0.61	0.61	—	—				
13	2	0.52	0.54	—	—				
14	4	0.31	0.48	2	6.9	7.2	2	0.52	0.56
Average		0.38							
21	12	0.11	0.23	8	7.3	10.1	8	0.38	0.55
22	4	0.17	0.18	2	5.5	5.8	2	0.26	0.26
Average		0.13	—	—	6.9	—	—	0.36	—

Table 4.—Reduction of oriental fruit moth injury to ripe peach fruits by parathion, DDT, and EPN sprays, and residue on fruit at harvest.

Insecticides	Application Dates	Orchard No.	Period Between Last Spray and Sampling for		Residue at Harvest			Reduction of Injury	Injury in Untreated Fruits
			Analysis	Fruit Injury	Parathion	DDT	EPN		
	1950		days	days	p.p.m.	p.p.m.	p.p.m.	per cent	per cent
Parathion	July 11, 24, and Aug. 7	1	15	16	0.31	—	—	92.0	12.5
	July 12, 24, and Aug. 7	2	14	14	0.28	—	—	95.7	34.5
		3	11	11	0.44	—	—	100.0	5.0
	July 11 and 31	1	22	23	0.15	—	—	76.0	12.5
	July 12 and Aug. 1	2	20	20	0.08	—	—	94.2	34.5
	July 12 and Aug. 2	3	16	16	0.13	—	—	90.0	5.0
Parathion followed by DDT	July 11 and 31	1	22	23	0.03[1]	5.6	—	52.0	12.5
	July 12 and Aug. 1	2	20	20	0.04[2]	5.7	—	87.0	35.6
	July 12 and Aug. 2	3	16	16	0.05[3]	6.1	—	60.0	5.0
DDT followed by parathion	July 11 and 31	1	22	23	0.10	4.0[1]	—	76.0	12.5
	July 12 and Aug. 1	2	20	20	0.09	3.3[2]	—	95.7	34.5
	July 12 and Aug. 2	3	16	16	0.10	3.6[3]	—	90.0	5.0
	1951								
Parathion	July 9, 23, and Aug. 6	1	7	7	0.61	—	—	81.0	31.5
		2	14	10	0.52	—	—	92.9	70.5
	July 10, 24, and Aug. 8	3	13	8	0.46	—	—	100.0	4.0
	July 9 and 30	1	14	14	0.15	—	—	79.4	31.5
		2	21	17	0.12	—	—	87.9	70.5
	July 10 and 30	3	21	17	0.07	—	—	50.0	4.0
Parathion followed by DDT	July 9 and 30	1	14	14	—	6.8	—	77.8	31.5
		2	21	17	—	6.5	—	91.5	70.5
	July 10 and 30	3	21	17	—	5.5	—	100.0	4.0
EPN	July 9 and 30	1	14	14	—	—	0.52	79.4	31.5
		2	21	17	—	—	0.54	83.0	70.5
	July 10 and 30	3	21	17	—	—	0.44	87.5	4.0

[1] After 42 days. [2] After 40 days. [3] After 38 days.

The residues on all ripe-fruit samples taken in 1950 and 1951 were arranged in groups 1, 2, and 3 weeks between the last spray application and sampling in order that weekly averages might be obtained. For example, the residues on all samples that were picked 11 to 17 days after the last application were averaged and considered as samples picked 2 weeks after the last application. The average parathion residue observed was less than one-half the amount reported by Walker (1950).

DDT was applied only once in each schedule in which it was used. Despite the limitation in its use the original deposit of DDT was about six times the deposit of parathion or EPN. Since only about 50 per cent of the residue on fruit was lost during 3 weeks after application (Table 2), it is not surprising that DDT residue was comparatively great on ripe fruit. The persistence of DDT residue on ripe fruit was demonstrated further by an experimental schedule replicated in three orchards in which DDT was applied approximately 6 weeks and parathion 3 weeks before harvest (Table 4). In these observations the average DDT residue on ripe fruit was 3.6 p.p.m., and was approximately the same as that previously reported by the authors (1950).

EFFECTIVENESS OF SPRAY SCHEDULES IN REDUCING INJURY TO RIPE FRUIT.—The insecticides, spray schedules, and their effectiveness in reducing oriental fruit moth injury to ripe fruit are shown in table 4. The percentages of ripe fruit injured in all sprayed plots were significantly different from the percentage in the control plots in all experimental orchards except orchard 3 in 1951. In this orchard fruit injury was not sufficiently great for a significant difference to be shown between experimental and control plots. There was no significant difference in the effectiveness of the different schedules in reducing injury to ripe fruit. The average reduction of injury was 84.1 per cent in 24 tests. Although injury to ripe fruit was greatly reduced by spray schedules containing DDT, the amount of DDT residue on ripe fruit sprayed 3 weeks before harvest indicated that this insecticide probably should not be used in the last spray. DDT could be used in an earlier spray without danger of excessive residue on fruit at harvest time.

SUMMARY.—Studies were made in 1950 and 1951 in the vicinity of Moorestown, New Jersey, of the loss of parathion, DDT, and EPN residues from Summercrest and Elberta peach leaves and immature fruit, residue on fruit at harvest, and the effectiveness of these insecticides in different spray schedules to control the oriental fruit moth *Grapholitha molesta* (Busck), in ripe fruit. During 1, 2, and 3 weeks following application the average rates of residue loss from leaves were as follows: Parathion, approximately 94, 99, and 100 per cent; DDT, 70, 76, and 85 per cent in 1950 and 33, 46, and 53 per cent in 1951; and EPN, 83, 92, and 97 per cent, respectively. Parathion and EPN residues were lost at a considerably lower rate from fruit than from leaves, but DDT residue was lost from fruit and leaves at about the same rate. The average residues on ripe fruit 2 and 3 weeks after application were as follows. Parathion, 0.24 and 0.10 p.p.m.; DDT, 6.4 and 5.9 p.p.m.; and EPN, 0.52 and 0.36 p.p.m., respectively. There was no significant difference between the spray schedules tested in reducing oriental fruit moth injury to ripe fruit. The average reduction of ripe fruit injury was 84.1 per cent.

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Orchard Evaluation of DDT Formulations and DDT-Acaricide Combinations[1]

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A study of some DDT wettable powder formulations was initiated with the hope of lowering harvest residues on food crops without sacrificing insect control. Two approaches were used. Formulations of DDT having the toxicant impregnated on the carrier were applied in an effort to achieve satisfactory pest control with lower concentrations and combinations of toxicants (DDT+acaricide) were used to prevent the build up of mites and to supplement the action of DDT against insects, permitting lower concentrations of DDT to be used; thus the DDT residues might be lowered considerably.

In the past, impregnated DDT dusts were found to be superior to mechanically mixed dusts for the control of some vegetable insects by numerous workers (Apple 1945, Brooks & Anderson 1947, and Ashdown & Watkins 1948). Better red-banded leaf roller control and lower residues were reported by Brown (1949)[1a] with an impregnated DDT wettable powder formulation than with a mechanically mixed DDT formulation. The addition of 2.5 ounces of 25 per cent parathion to 1.5 pounds of 50 per cent DDT in four cover sprays gave satisfactory control of mites but did not improve the codling moth control for Newton & List (1948). McAlister *et al.* (1949) obtained excellent control of codling moth, red-banded leaf roller, and two-spotted mites when 0.25 pounds of 25 per cent parathion were included in each of the DDT cover sprays. One-half pound of 15 per cent parathion in the DDT cover sprays has given excellent control of orchard mites (Dean & Newcomer 1948, Hamilton 1951).

The laboratory phase of the study was concerned with formulations in which the DDT was coated on the carrier by a fusion

[1] This work was supported in part by a Tobacco By-Products and Chemical Corporation fellowship and a J. M. Huber grant.

[1a] Brown, L. R. 1949. Investigations with certain low and high volume insecticide applicators by wet dusting and mist spraying of apple trees. Ph.D. Thesis, Cornell University Library, Ithaca, New York.

process and was reported by Harrison (1951). He used two experimental formulations of "fused" DDT in comparison with a conventionally prepared formulation. In one of the experimental formulations the DDT was fused on *Barden Clay*[2] while in the other the DDT was fused on an organic carrier[3] made of extracted tobacco stems. In biological and chemical studies Harrison found the conventional formulation to be inferior to the "fused" formulations in initial and residual effectiveness.

The field work on which the results of this report are based was in Wayne County, New York. Six experiments were conducted in apple orchards for the control of apple pests during two summer seasons. Two experiments, one with dilute spray and the other with concentrate spray (8X), were run in 1950. Four experiments, three with dilute spray and one with concentrate spray (6X), were run in 1951. Only the treatments pertinent to this report are listed.

EXPERIMENTS AND MATERIALS.—*1950 Experiments.*—Experiment I, Cornwall Farm, Pultneyville, N. Y. The following treatments were applied on Cortland apple trees in the 10-day and four cover sprays with a mist concentrate sprayer (Brann & Gunkel 1951):

Formulation	*Pounds per 100 Gallons*
Conventional 50% DDT[4]	16
Tobacco 25% DDT[5]	24
Tobacco 25% DDT+3% Para (Fm)[6]	24

A paste or a wettable sulphur was included in each cover spray for the control of apple scab. A block of 300 Cortland apple trees was divided into 20 plots, each plot three trees wide and five trees long. Five treatments were randomized throughout the block, thus making four replicates of each treatment. Two trees in the center of each plot were used for obtaining both insect control and insecticide residue data.

Experiment II, Andrews Farm, Sodus, N.Y. The following treatments were applied on McIntosh apple trees in the 10-day

Formulation	*Pounds per 100 Gallons*
Conventional 50% DDT	2
Tobacco 25% DDT+3% Para (Fm)	2
Tobacco 25% DDT+3% Para (Fm)	3
Barden Clay 25% DDT	4

and four cover sprays with a hydraulic, high pressure sprayer. A paste sulphur was included in each spray for apple scab control. Ten treatments were randomized throughout the block in single tree plots, making seven replicates for each treatment.

1951 Experiments.—Experiment I, Andrews Farm, Sodus, N. Y. Nineteen treatments were randomized throughout a McIntosh block in single tree plots to give five replicates for each treatment. The following treatments are reported here:

Formulation	*Pounds per 100 Gallons*
Conventional 50% DDT	1.5
Conventional 50% DDT	2.0
Tobacco 25% DDT	2.0
Tobacco 25% DDT	3.0
Tobacco 25% DDT	4.0
Barden clay 25% DDT	2.0
Barden clay 25% DDT	3.0
Barden clay 25% DDT	4.0
Tobacco 25% DDT+3% Para (Fm)	1.0
Tobacco 25% DDT+3% Para (Fm)	2.0
Tobacco 25% DDT+3% Para (Fm)	3.0

A hydraulic, high pressure sprayer with a single nozzle, trigger gun was used to apply four cover sprays from the ground. A paste or a wettable powder sulphur was included in each cover spray for apple scab.

Experiment II, Poray Farm, Sodus, N. Y.—Five treatments were applied to McIntosh apple trees at 6X concentration with a fixed outlet mist sprayer (Parker 1950) in four cover sprays. The following treatments are reported here:

Formulation	*Pounds per 100 Gallons*
Conventional 50% DDT	12
Tobacco 25% DDT	24
Barden clay 25% DDT	24
Tobacco 25% DDT+3% Para (Fm)	24

A glyoxalidine at six quarts per 100 gallons was used as a fungicide in the cover sprays. A block of 323 trees was divided into 20 plots, each plot three or four trees wide and five trees long. Five treatments were randomized throughout, making four replicates for each treatment. The two center trees of each plot were used as data trees.

[2] J. M. Huber Corporation.
[3] Tobacco By-Products and Chemical Corporation.
[4] Niagara Chemical Division, Food Machinery and Chemical Corp.
[5] "Fused" 25% DDT, Tobacco By-Products and Chemical Corp.
[6] "Fused" 25% DDT formulated with parathion, Tobacco By-Products and Chemical Corp.

Experiment III, Porter Farm, Sodus, N. Y.—Sixteen treatments were randomized throughout a 104 tree McIntosh block in single tree plots to make six replicates of each treatment. The following treatments are reported here:

Formulation	Pounds per 100 Gallons: DDT	Pounds per 100 Gallons: Acaricide
Tobacco 25% DDT	3.0	
Conventional 50% DDT+15% Para (TM)[7]	1.5	.6
Tobacco 25% DDT+15% Para (TM)	3.0	.6
Barden clay 25% DDT+15% Para (TM)	3.0	.6
Tobacco 25% DDT+15% Para (TM)	3.0	.6
Tobacco 25% DDT+27% EPN (TM)	3.0	.33
Barden clay 25% DDT+27% EPN (TM)	3.0	.33
Barden clay 25% DDT+20% DMC (TM)	3.0	.45
Barden clay 25% DDT+15% Para (TM)	3.0	.6
Tobacco 25% DDT+3% Para (Fm)	3.0	
Tobacco 25% DDT+3% EPN (Fm)	3.0	
Tobacco 25% DDT+3% DMC (Fm)	3.0	

A hydraulic, high pressure sprayer with a single nozzle trigger gun was used to apply four cover sprays from the ground. A wettable sulphur was included in each cover spray for scab control.

Experiment IV, Poray Farm, Sodus, N. Y.—The following treatments were randomized throughout a 144 tree block of R. I. Greening apple trees in single tree plots to make six replicates of each treatment:

Formulation	Pounds per 100 Gallons: DDT	Pounds per 100 Gallons: Acaricide	Spray Interval in Days
Conventional 50% DDT	1.5		10
	1.5		14
	1.5		18
Tobacco 25% DDT	3.0		10
	3.0		14
	3.0		18
Barden clay 25% DDT	3.0		10
	3.0		14
	3.0		18
Tobacco 25% DDT+15% Para (TM)	3.0	0.6	10
	3.0	0.6	14
	3.0	0.6	18
Tobacco 25% DDT+27% EPN (TM)	3.0	0.33	10
	3.0	0.33	14
	3.0	0.33	18
Barden clay 25% DDT+15% Para (TM)	3.0	0.6	10
	3.0	0.6	14
	3.0	0.6	18
Conventional 50% DDT+15% Para (TM)	2.0		10
	2.0		14
	2.0		18

The treatments that were applied every 10 days had six cover sprays. The 14-day treatments had five cover sprays, and the 18-day treatments had four cover sprays. A hydraulic, high pressure sprayer with a single nozzle trigger gun was used to apply the cover sprays from the ground. The fungicide applied to the trees in this experiment for apple scab control was a glyoxalidine at one quart per 100 gallons.

METHODS.—Mite counts were made midway between cover sprays during the period of the heaviest mite population. Samples of 30 spur leaves per tree per treatment were selected at each sampling date. The first counts were made with the aid of binocular microscopes in the field. In later counts the leaf samples were fumigated with ethylene chloride and brushed on glass plates (Henderson & McBurnie 1943); then binocular microscopes were used to count the mites on the glass plates.

The data on the fruit injury caused by codling moth and red-banded leaf roller were taken from the preharvest drops and a 500 fruit sample from the harvested fruit of each data tree. Total codling moth injury included fruit injury by either stings or entries. Injury caused by red-banded leaf roller was tabulated as total injury (fruits injured by first or second broods or both), first brood injury, and second brood injury. Generally the differences for second brood control were similar to those for the control of total red-banded leaf roller injury. Analysis of variance was used in analyzing the fruit injury and residue data.

In 1950 and 1951 a residue study of the foliage and fruit was made of samples (100 leaf discs per sample and ten to thirty fruits per sample) taken before and after the third and fourth cover sprays and at harvest. One leaf sample and one fruit sample was taken from each treatment studied at each sampling date. The leaf samples were taken with a leaf punch directly into 250 ml. glass bottles and the fruit for samples were cut from the tree and allowed to drop into gallon glass jars; these samples were taken immediately before and after application and stored at 40° F. The samples were stripped of toxicant in the same containers the following day and analyzed or stored. The parathion and EPN samples were analyzed immediately after stripping.

Three DDT formulations and three DDT+acaricide combinations, tank-mixed and formulated, were used to make the comparisons shown in the tables which follow. In all of the formulations and combinations 0.75 pounds of actual

[7] Tank-mixed—The DDT and the acaricide were added to the spray tank separately just prior to spraying.

DDT per 100 gallons were used unless otherwise designated. The acaricide (in the DDT+acaricide combinations) was used at the rate of 0.09 pounds of actual toxicant per 100 gallons.

The data in each table include all the results of the 1950 and 1951 experiments in which the desired combinations could be directly compared. The number of treatments used in figuring the averages is indicated in the number of comparisons column. In figuring the per cent control the treatments were compared with checks (untreated trees). The three types of DDT formulations and the formulated DDT+parathion combination head the four columns of data presented in most of the tables. In the lower part of some of the tables the acaricide has been added as tank-mixes (TM) to only the three DDT formulations.

RESULTS AND DISCUSSION:—In the control of codling moth there was very little difference in the DDT formulations (Table 1). The DDT+parathion formulation was significantly[8] superior to DDT alone; this formulation compared favorably with the tank-mix of the separate toxicants in equivalent proportions. In

Table 1.—Codling moth. Average per cent control.

No. Comparisons	Conventional Formulation	"Fused" Formulations		
		Barden Clay	Tobacco	Tobacco DDT+Para
2	87	87	88	95
6	88	87	89	—
	+Para (TM)			
1	93	95	89	94
5		94	91	

the tank-mixed combinations of DDT+parathion the tobacco combination tended consistently to be the poorest and the Barden clay combination the best, altough the differences were not significant in the individual experiments.

Three dosage levels of actual DDT for codling moth control are compared in table 2. The one pound level for all formulations was significantly superior to the one-half pound level; however the three-quarter pound level was not significantly superior to the one-half pound level. Although the data are not shown for all the comparisons, the DDT+parathion formulation (0.75 pounds of actual DDT) was consistently as effective as the one pound level of actual DDT alone.

Table 2.—Codling moth. Average per cent control.

Act. DDT P/100 g.	Conventional Formulation	"Fused" Formulations		
		Barden Clay	Tobacco	Tobacco DDT+Para
0.50	—	77	84	85
0.75	90	86	90	93
1.00	94	88	90	94

In 1950 most of the red-banded leaf roller injury to the fruit was caused by the second brood. However, in most of the 1951 experiments first brood had caused some fruit injury before the first cover sprays were applied; hence, the comparisons presented here are only those on second brood injury.

As in the control of codling moth the DDT+parathion formulation was significantly superior to the DDT formulations in the control of red-banded leaf roller (Table 3). In both comparisons of DDT alone, the Barden clay formulation was consistently inferior to the others, although this difference was not statistically significant. There was very little difference between the various tank-mixed combinations of DDT+parathion, or the tank-mixed and the formulated combinations. The increase in control of both codling moth and red-banded leaf roller by the addition of parathion (tank-mixed) was consistently greatest for the Barden Clay combination.

The importance of the spray interval against the red-banded leaf roller is shown in table 4; here the data are comparable both vertically and horizontally. The DDT+parathion combinations were significantly superior to the DDT+EPN and DDT alone in the control of red-banded leaf roller. The control of DDT+parathion in the 10-day interval was not superior to that of the 14-day interval; however, the 10 and 14 day intervals were significantly superior to the 18-day interval. The control with the 18-day interval was about the same as that shown in the lower half of table 3 where the treatments were applied at an interval of 15 days or longer in the cover sprays.

[8] Significant at the 1 per cent level.

Table 3.—Second brood red-banded leaf roller. Average per cent control.

No. Comparisons	Conventional Formulation	"Fused" Formulations		
		Barden Clay	Tobacco	Tobacco DDT+Para
2	36	33	36	80
6	48	38	49	—
	+Parathion (TM)			
1	83	81	79	84
5	—	88	87	—

Table 4.—Second brood red-banded leaf roller. Average per cent control.

Formulation	Spray Interval (days)		
	10	14	18
Tobacco DDT	57	61	36
Barden clay DDT	46	29	33
Tobacco DDT+Parathion	95	94	81
Barden clay DDT+Parathion	95	94	84
Tobacco DDT+EPN	87	78	73

The DDT+EPN combination was superior to the DDT formulations for the control of red-banded leaf roller. The 10-day interval was superior to the 14-day interval and significantly superior to the 18-day interval.

Excellent control of European red mites was obtained with the DDT+parathion combination both in 1950 and 1951. This combination was significantly superior to DDT alone (Table 5). The formulated DDT+parathion combination was superior to the tank-mixed combinations.

Table 5.—European red mite. Per cent control.

No. Comparisons	Conventional Formulation	"Fused" Formulations		
		Barden Clay	Tobacco	Tobacco DDT+Para
1	43	50	50	97
2	55	—	—	96
	+Parathion (TM)			
1	84	88	81	100

Data on the control of the two-spotted mites were taken in Experiment I 1950, Experiment III 1951, and in several special mite tests. In all observations, the DDT+parathion combination gave very good control and was significantly superior to the DDT treatments (Table 6). Differences between the tank-mixed and the formulated DDT+parathion combinations were not great enough for statistical significance; however, the tobacco combination was consistently better than the Barden clay combination.

EPN, DMC, and parathion were used with DDT as formulated and tank-mixed combinations (Table 7). The tank-mixed DDT+EPN combinations was slightly superior to the formulated in the control of two-spotted mites and was significantly superior to the formulated in

Table 6.—Two spotted mites. Per cent control.

No. Comparisons	Conventional Formulation	"Fused" Formulations		
		Barden Clay	Tobacco	Tobacco DDT+Para
1	30	—	35	99
	+Parathion (TM)			
3	—	89	94	97
6	—	90	94	—

the control of red-banded leaf foller. Codling moth control was about the same for the two types of combinations. The DDT+EPN combination was signifi-

Table 7.—Comparison of acaricides. Per cent control.

No. Comparisons	DDT+EPN		DDT+DMC		DDT+Para	
	TM	FM	TM	Fm	TM	Fm
	Two-spotted mite					
3	96	92	97	82	97	95
6	95	—	92	—	92	—
	Second Brood Red-Banded Leaf Roller					
1	82	69	64	53	88	84
7	78	—	—	—	85	—
	Codling Moth					
1	89	91	92	87	88	93
7	93	—	—	—	93	—

cantly superior to the DDT+DMC combination for red-banded leaf roller control. The formulated DDT+DMC was inferior to the tank-mixed combination in all comparisons; the red-banded leaf roller control obtained by the tank-mixed combination was highly significant over that of the formulated.

The differences in control between the tank-mixed and the formulated combinations were less for DDT+parathion than for DDT+EPN and DDT+DMC. In fact, the formulated DDT+parathion consistently resulted in somewhat better control of two-spotted mites and codling moth although the differences were not statistically significant. The DDT+parathion combination was significantly superior to the DDT+EPN and DDT+DMC for the control of red-banded leaf roller. About the same control of codling moth and two-spotted mites was obtained with DDT+parathion and DDT+EPN.

The results of a study of the DDT residues on apple fruit are shown in table 8. The Barden clay formulation of DDT consistently deposited more DDT per spray on the fruit than the conventional and tobacco formulations and had higher residues at the end of weathering periods. The per cent loss was usually highest for the tobacco formulation, thus resulting in the lowest residues at the end of weathering periods.

In all of the experiments with dilute spray, the formulated DDT+parathion combination had deposits equal to or higher than the Barden clay DDT formulation. The per cent loss of the formulated combination was equal to or higher than the tobacco DDT formulation; but, due to the higher deposits, the DDT residues were somewhat higher for the combination.

In the tank-mixed combinations (DDT+Para) the Barden clay formulation deposited more DDT on the fruit than the tobacco formulation; this was about the same as the DDT deposits of the formulated DDT+parathion. It is interesting to note that the per cent loss for tobacco DDT in the tank-mix was about the same as that of the Barden clay DDT. The addition of parathion in the tank-mixes lowered the DDT deposits and residues on fruit in both the Barden clay and tobacco formulations.

The tank-mixed DDT+EPN combinations had somewhat higher DDT residues than the tank-mixed DDT+Para and the formulated DDT+EPN combinations. The deposit and per cent loss of the tank-mixed DDT+EPN were higher than that of the tank mixed DDT+parathion for the tobacco formulation only.

The results of the study of the DDT residues on apple foliage are shown in table 9. The deposits and residues of DDT per unit area were generally lower for the foliage than for the fruit. The per cent loss for the foliage was much higher than that of the fruit. The rate of loss on the foliage was usually higher for the conventional and *Barden Clay* formulations than for the tobacco formulation; this was the main reason why the residues were higher for the latter formulation.

The addition of parathion to DDT (TM) decreased the deposits and residues of DDT on the foliage to both the Barden clay and the tobacco formulations. The efficiency[9] of the tobacco formulation was reduced more than that of the Barden clay formulation; this was due primarily

Table 8.—Average deposit, per cent loss, and residue of DDT on apple fruit.

No. Comparisons	Conventional Formulation	"Fused" Formulations		
		Barden Clay	Tobacco	Tobacco DDT+ Para
Deposit[1] 2	5.1	6.1	5.3	6.5
%Loss[2] 2	31.0	31.0	43.0	42.0
Residue[3] 2	3.2	3.9	2.8	3.8
R/D[4]	0.61	0.64	0.53	0.58
Deposit 3	4.3	5.0	4.6	
% Loss 3	32.0	34.0	39.0	
Residue 3	3.0	3.3	2.6	
R/D	0.70	0.66	0.58	
		+Para (TM)		
Deposit 1		5.3	2.9	5.4
% Loss 1		33.0	31.0	56.0
Residue 1		3.5	2.3	2.8
R/D		0.66	0.79	0.53
Deposit 2		4.6	3.1	
% Loss 2		39.0	31.0	
Residue		2.9	2.3	
R/D		0.63	0.74	
		+EPN (TM)		+EPN (Fm)
Deposit 1		4.3	5.9	4.4
% Loss 1		23.0	43.0	49.0
Residue 1		3.7	2.8	2.4
R/D		0.87	0.48	0.55

[1] The average of the deposits (Mcg./cm.^{2}) for the third and fourth cover sprays.

[2] The average per cent loss due to weathering during two weathering periods, from third to fourth cover sprays and fourth cover spray to harvest.

[3] The average of the residues (Mcg./cm.^{2}) at the end of three weathering periods, second to third cover spray, third to fourth cover spray, and fourth cover spray to harvest.

[4] The R/D ratio was determined by dividing the average residue to the average deposit.

[9] Figured as the amount of residue maintained per unit of deposit (R/D).

to the increase in the per cent loss of the tobacco formulation.

The deposits and residues of parathion are shown in table 10. The parathion deposits of the formulated combination were 1.5 to 2.0 times higher than the tank-mixed combination. The deposits on the fruit were higher than those on the foliage. All of the residues at the end of weathering periods 15 days or longer were less than 0.1 Mcg./cm. During the 1950 and 1951 seasons visible parathion injury to the fruit or foliage was not observed in the DDT+parathion treatments when applied either in the dilute or the concentrate spray to McIntosh, Cortland, and R. I. Greening varieties.

Most of the DDT+EPN combinations deposited more EPN on the foliage than on the fruit (Table 11). The EPN residues on the foliage for this combination were about three times higher than the parathion residues on the foliage of the DDT+parathion treatments. The amount of EPN and parathion residues on the fruit was about the same. EPN injury to the fruit or foliage was not observed in treatments with this combination.

Table 9.—Average deposit. Per cent loss and residue of DDT apple foliage.

No. Comparisons	Conv. DDT Form.	"Fused" DDT Formulations* Barden Clay	Tobacco	Tobacco DDT+ Para
Deposit 2	5.8	5.0	4.1	5.5
% Loss 2	75.0	76.0	57.0	70.0
Residue 2	1.6	1.9	3.1	3.0
R/D	0.28	0.38	0.76	0.55
Deposit 3	4.7	4.2	4.2	
% Loss 3	70.0	72.0	57.0	
Residue 3	1.6	1.6	2.7	
R/D	0.33	0.38	0.65	
		+Para (TM)		
Deposit 1	2.2	2.7	3.4	2.4
% Loss 1	62.0	76.0	78.0	66.0
Residue 1	0.9	0.8	0.9	1.1
R/D	0.43	0.31	0.27	0.45
Deposit 2		3.2	3.1	
% Loss 2		73.0	68.0	
Residue 2		1.0	1.4	
R/D		0.31	0.46	
		+EPN (TM)		+EPN (Fm)
Deposit 1		2.9	3.3	3.0
% Loss 1		76.0	68.0	73.0
Residue 1		0.8	1.2	1.0
R/D		0.29	0.36	0.33

* Harrison, R. J. R. 1951. Laboratory evaluation of two experimental formulations of DDT and one experimental formulation of toxaphene in comparison to a common commercial formulation. M.S. Thesis, Cornell University Library, Ithaca, New York.

Table 10.—Deposit and residue of parathion on apple fruit and foliage (Mcg./cm.²).

No. Comparisons	DDT+Parathion (TM) Conventional	Barden Clay	Tobacco	DDT+ Para (Fm) Tobacco
	On Apple fruit			
Deposit 1	.46	.52	.54	.71
Residue 1	.03	.04	.05	.06
	On apple foliage			
Deposit 1	.25	.30	.30	.63
Residue 1	.03	.04	.04	.05

Table 11.—Deposit and residue of EPN on apple fruit and foliage (Mcg./cm.²).

No. Comparisons	DDT+EPN (TM) Barden clay	Tobacco	DDT+EPN (Fm) Tobacco
	On apple fruit		
Deposit 1	.32	.45	.33
Residue 1	.06	.07	.05
	On apple foliage		
Deposit 1	.59	.31	.58
Residue 1	.11	.13	.20

The DDT residues on the fruit at harvest are for the treatments with 0.75 pounds of actual DDT either alone or in combination with 0.09 pounds of actual acaricide in four cover sprays (Table 12). The last row of residues in table 12 are the average of all treatments for each formulation.

Table 12.—DDT residues on the fruit at harvest (PPM).

No. Comparisons	Conventional Formulation	"Fused" Formulations Barden Clay	Tobacco	Tobacco DDT+ Para
2	5.0	7.2	4.3	4.3
4	4.1	5.1	3.8	—
		+Parathion (TM)		
1	5.5	6.5	3.8	3.7
4	—	5.7	4.0	—
		+EPN (TM)		
1	—	6.3	6.1	3.7
(All)*	(8)4.3	(11)5.3	(13)3.9	(5)3.7

* The number in the parentheses refers to the number of treatments used in calculating the average residue which follows.

In all of the comparisons, with the exception of the tank-mixed DDT+EPN combination, the tobacco DDT formulation consistently produced the lowest harvest residues on the fruit while the *Barden Clay* formulation consistently had the highest residues. The harvest residues on the fruit were about one-third less for the treatments with 0.75 pound of actual DDT per 100 gallons than those with 1.0 pound. When parathion was added to 0.75 pound of actual DDT in the cover sprays the harvest residues were slightly lower than when 1 pound of actual DDT was used alone and the control of red-banded leaf roller and mites was increased significantly; the tobacco DDT in this combination lowered the harvest residues about 10 per cent more than the conventional formulation. The formulated DDT+parathion had higher deposits of DDT and parathion, about the same harvest residues, and somewhat better pest control than the tank-mixed.

SUMMARY AND CONCLUSIONS.—During the 1950 and 1951 seasons six field experiments were conducted in apple orchards to compare "fused" (*Barden clay* and tobacco) and conventional formulations of DDT and DDT+acaricide combinations (DDT+Para, DDT+EPN, and DDT+DMC) for the control of apple pests. Foliage and fruit residue studies were made to compare the depositing, weathering, and residues of the different formulations and combinations.

The fused and conventional formulations of DDT gave about the same control of codling moth, red-banded leaf roller, and mites. The *Barden clay* formulation had the highest deposits and residues on the fruit while the tobacco formulation maintained the highest residues on the foliage. Significant differences in pest control resulting from differences in deposits, weathering, and residues of the DDT formulations were not noted. Harvest DDT residues of the tobacco formulation on the fruit were considerably lower than the conventional and *Barden clay* formulations; when this formulation was used alone or in the DDT+parathion combination, the DDT harvest residues were 10 per cent or more below those of the conventional formulation. Lowering the dosage level of actual DDT from 1.0 pounds per 100 gallons to 0.75 pound resulted in about a one-third reduction in the harvest residue without a significant increase in insect injury.

The DDT+parathion combination when used in each of the cover sprays on apples gave excellent control of codling moth, red-banded leaf roller and mites; this combination (0.75 pound of actual DDT+0.09 pound of actual parathion) was significantly superior to 0.75 pound of actual DDT in the control of each of the above pests. A spray interval of 14 days or less was necessary for good control of red-banded leaf roller with this combination. The formulated combination gave better mite control than the tank-mixed; perhaps, this was due in part to the higher parathion deposits in the treatments with the formulated combination. Although the weathering (per cent loss of DDT) of the formulated combination was greater than that of the tank-mixed, the residues were about equal in amount and there was very little difference in insect control of the two combinations.

The control of codling moth and mites was not greatly different for the DDT+parathion, DDT+EPN, and DDT+DMC tank mixed combinations. However, the DDT+parathion combination was significantly superior to the DDT+EPN and the DDT+DMC combintions in the control of red-banded leaf roller; there was not great enough difference in the deposits and residues of these combinations to explain this difference in control.

The tank-mixed DDT+EPN combination was superior to the formulated in the control of codling moth, red-banded leaf roller, and mites although the deposits and residues of DDT and EPN were not greatly different for the two types of combinations. This combination gave significantly better control of red-banded leaf roller than the DDT+DMC combination. The red-banded leaf roller control for the 10-day interval was superior to that of the 14-day interval and significantly superior to that of the 18-day interval.

The tank-mixed DDT+DMC combination gave significantly better control of red-banded leaf roller than the formulated. The control of codling moth and mites was also better for the tank-mixed combination.

The residues of parathion and EPN were about equal in amount on the apple fruit while on the foliage the EPN residues were about three times higher than the parathion residues. For two seasons (1950 and 1951) parathion injury to fruit or foliage has not been observed when the DDT+parathion combination was applied in dilute or concentrate spray to the McIntosh, Cortland, and R. I. Greening varieties. There was not visible EPN injury to the fruit or the foliage in the DDT+EPN treatments applied to the McIntosh variety.

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Control of Rootworms Affecting Peanuts[1]

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The southern corn rootworm, *Diabrotica undecimpunctata Howardi* Barber, has been a serious pest of peanuts in North Carolina for many years, especially on heavier soils. Counts made at Rocky Mount, in 1948, in a number of peanut plots, showed an average of 55 per cent of the peanuts injured by this pest. On some farms injury has been so severe during the past few years that the crop was almost a total loss. A survey made in August of 1951, throughout the peanut area of northeastern North Carolina revealed an average of 37 per cent of the peanuts with rootworm damage.

Rootworms injure peanuts in several ways. Early in the season when young plants are emerging the larvae gnaw the surface of the underground stems and may tunnel through the cotyledons. Later, when pegging begins, rootworms attack the pegs themselves often destroying the tips of the pegs which would normally form pods. Still later, and continuing until digging time, rootworms tunnel through and feed on the immature and mature pods. Depending upon the severity of this attack rootworms reduce peanut yields and also have an adverse affect on the quality of the nuts as reflected in lower shelling percentages.

COOPERATING AGENCIES.—In the course of experimental work at the Rocky Mount Experiment Substation, it was soon realized that control of rootworms would be necessary for the obtaining of accurate data from plots where plant disease, variety testing, fertilization and other work was being carried on. With this in mind, Cooper, plant pathologist, and York, agronomist, with the advice of Kulash, entomologist, compared a number of insecticides in 1949 and 1950, for rootworm control in field plots. This testing program was expanded in 1951 by Ritcher, entomologist, assisted by McClain & Weisman, graduate assistants. Other groups which have contributed substantially to the project include the Horticulture Food Processing Laboratory, the Institute of Statistics and U.S.D.A. Bureau of Plant Industry.

METHODS.—Field tests have been made

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at the Rocky Mount Station comparing soil fumigants, insecticide-fertilizer mixtures, and insecticidal sprays and dusts. Plot size has been standardized at 0.125 acre with 4 replicates of each treatment in a randomized block setup. Insecticide-fertilizer mixtures were applied by hand to an open furrow in the center of each row and mixed with the soil just prior to planting. Dusts were applied to the peanut foliage and adjacent soil with a rotary hand duster. Sprays were applied to foliage and adjacent soil with a 3-gallon sprayer. Dusts and sprays were applied after emergence or during the early blooming or early pegging period.

Final counts were made by classifying the pods from 10 plants selected at random, at or just before digging time in the fall. Plants from each plot were stacked on a separate pole and yields obtained by thrashing each stack after field curing. Shelling percentages were obtained by shelling a 500 gram sample from each plot and the gross yields were adjusted accordingly.

TESTS IN 1949.—In the 1949 tests 5 per cent DDT dust (3 and 6 lbs./A) was compared with chlordane (1.5 and 3 lbs./A) and benzene hexachloride (1 lb./A) spray (Table 1). Comparisons were made as to best time of application. Results indicated that all three materials were effective at the amounts and times used but the per cent of injury in the check plot (32.6) was probably not high enough to make a severe test.

There was strong evidence from taste tests that the BHC treatment had caused an objectionable off-flavor in the oil-cooked and roasted peanuts and also in the peanut butter. Significant off-flavor was also picked up in the roasted peanuts from plots treated at early pegging time with chlordane but the peanut butter was unaffected.

Treated plots showed an increase in yield over the check plots, ranging from 529 to 836 pounds per acre. This was in part due to a significant difference between the shelling percentage of the check (45.3) and of treated plots (from 53 to 59.1).

1950 TESTS.—In the 1950 tests three insecticides, lindane (25% WP), chlordane (40% WP) and DDT (50% WP) each at two different rates, were applied in two ways, one in a fertilizer mixture at planting on April 25, and second as a spray on June 24 during the early blooming period. A fourth insecticide, heptachlor (25%WP) was applied in both ways but only at one rate, 2 pounds per acre. In addition, two soil fumigants, Dowfume W-40 and Dowfume N, were applied to the soil of two sets of plots on March 31, at rates of 15 gallons and 20 gallons per acre respectively.

Best control of rootworms was obtained with lindane in fertilizer at the rate of 1 lb./A, lindane spray, 0.25 lb./A and 1 lb./A, chlordane spray, 2 lb./A, and heptachlor in fertilizer and as a spray at 2 lb./A (Figure 1). DDT at 4 lbs./A afforded some control but was inferior to the other three insecticides. Both fumigants were ineffective for rootworm control.

Adjusted yields of peanuts per acre in the lindane sprayed plots, the chlordane plots at 2 lb./A, and in the heptachlor plots were significantly higher than in

Table 1.—Control of southern corn rootworms attacking peanuts. Rocky Mount, N. C., 1949

TREATMENT	TIME	TOXICANT P/A	P/AY	INJURED PODS (per cent)	MEAN NO. INJURED PODS
1. DDT (5% dust)	5/23—After Emergence	6	1569	6.1	26.2
2. DDT (5% dust)	7/12—Early Pegging	3	1771	8.2	34.5
3. DDT (5% dust)	5/23—After Emergence	3	1481	3.7	18.8
	7/12—Early Pegging	3			
4. DDT (5% dust)	7/12—Early Pegging	6	1557	15.7	54.2
5. Chlordane (40% WP) Spray	5/23—After Emergence	3	1634	3.5	12.4
6. Chlordane (40% WP) Spray	7/12—Early Pegging	1.5	1473	6.2	24.8
7. Chlordane (40% WP) Spray	7/12—Early Pegging	3	1464	3.6	15.5
8. BHC (6% gamma isomer) Spray	5/23—After Emergence	1	1680	2.0	7.0
9. Check	—	—	935	32.6	114.8
LSD (.05)			535		22.9
LSD (.01)			736		31.1

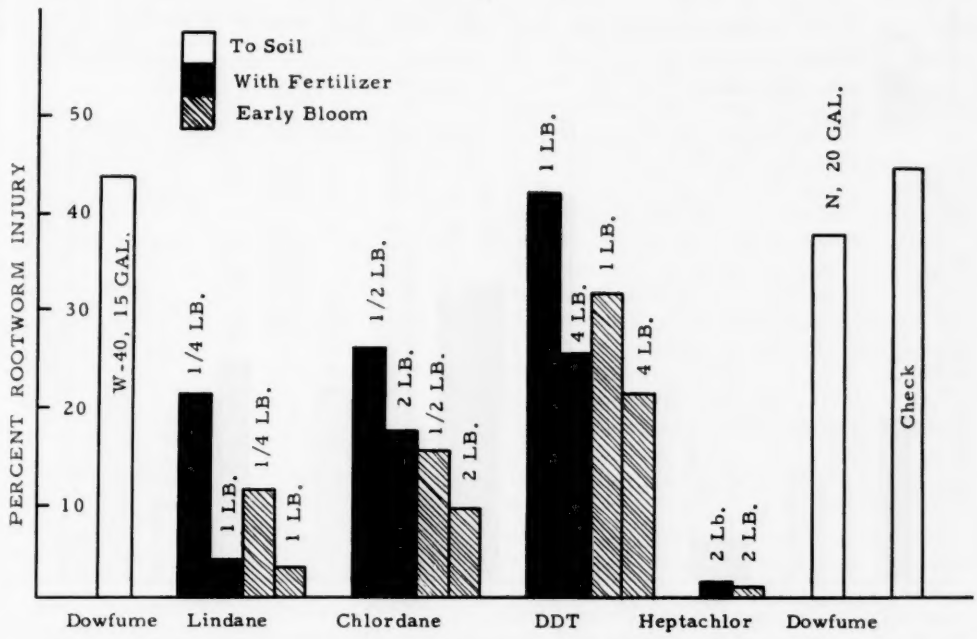

FIG. 1. Control of southern corn rootworms attacking peanuts, Rocky Mount, N. C., 1950, based on per cent of injured pods. LSD (.05) = 14.7 per cent. LSD (.01) = 19.6 per cent.

the check plots. In the case of the heptachlor plots this significant difference amounted to over 300 pounds per acre.

Samples of peanut butter and oil-cooked peanuts were prepared by Dr. J. H. Bettie of the Federal Bureau of Plant Industry. Taste panels supervised by the N. C. State College Food Processing Laboratory and Institute of Statistics indicated a significant off-flavor in peanut butter prepared from both series of plots treated with one pound of lindane per acre (Table 2). There was also indication of off-flavor in oil-cooked peanuts (but not in peanut butter) from the plots sprayed with chlordane at the rate of 2 pounds per acre and from plots treated at planting with a heptachlor-fertilizer mixture containing 2 pounds of heptachlor per acre.

1951 TESTS AT ROCKY MOUNT.—In the 1951 tests heptachlor (25% WP), aldrin (25% WP), and dieldrin (25% WP) were compared, at two different rates, in mixtures with fertilizer at the time of planting (May 1) and as dusts and sprays (also with wettable powders) during the early pegging period (July 6). Chlordane at the rate of 2 pounds per acre was tested in the three ways and was also applied as a spray at the rate of 4 pounds per acre. Toxaphene at the rate of 4 pounds per acre was also tested in the three ways. The application of chlordane spray at the rate of 4 pounds per acre and heptachlor spray at the rate of 2 pounds per acre resulted in rather severe injury to peanut foliage (20 to 25% foliage injured) which had the appearance of oil burn. The plants recovered from this injury, however, and yield was not affected.

Table 2.—Results of taste tests with peanuts from 1950 insecticide treated plots.[1]

TREATMENT	TOXICANT P/A	OIL-COOKED PEANUTS Score	OIL-COOKED PEANUTS Rank	PEANUT BUTTER Score	PEANUT BUTTER Rank
Lindane fert.	1 lb.	3.0	1	−2.5[2]	8
Lindane spray	1 lb.	−0.5	5.5	−2.0[2]	7
Chlordane fert.	2 lb.	0.0	4	−0.5	5
Chlordane spray	2 lb.	−3.0[2]	8	0.0	3.5
DDT fert.	4 lb.	1.0	3	−1.0	6
DDT spray	4 lb.	−0.5	5.5	0.0	3.5
Hept. fert.	2 lb.	−2.0[2]	7	2.5	2
Hept. spray	2 lb.	2.0	2	3.5	1

[1] Twenty-eight tasters used in tests of oil-cooked peanuts and 28 other tasters used in tests of peanut butter. Treated samples compared with untreated in each case.
[2] Significant off flavor.

Infestation by the southern corn rootworm was heavy in the test plot area during much of the growing season resulting in about 50 per cent injured pods

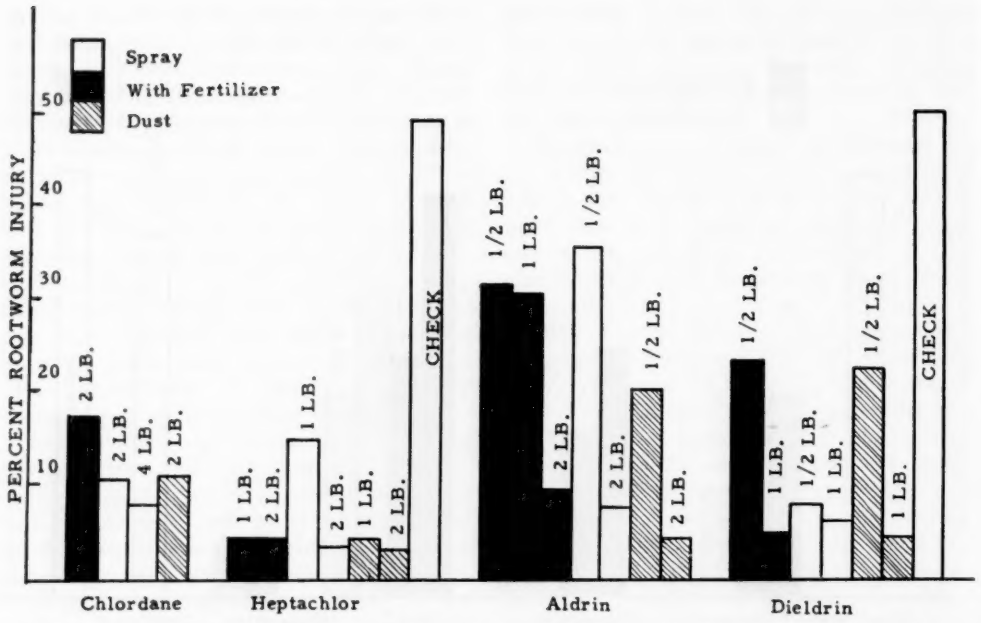

FIG. 2.—A comparison of the effectiveness of several insecticides for controlling southern corn rootworms attacking peanuts at Rocky Mount, N. C., 1951, based on percent of injured pods. LSD (.05) = 14.3 per cent. LSD (.01) = 19.0 per cent.

in untreated plots by harvest time (Figure 2). Effective control of rootworms was obtained with 1 and 2 pounds of heptachlor per acre, 2 pounds of aldrin and 1 pound of dieldrin whether applied in fertilizer mixtures, as a spray or as a dust. Statistical analysis indicated no significant difference between the results secured with the three materials at these rates. Chlordane also gave effective control when used as a spray at the rates of 2 and 4 pounds per acre and as a dust at 2 pounds per acre. Toxaphene used in all three ways at 4 pounds per acre was ineffective.

Yields of peanuts from the plots were very variable due in large part to soil differences. Adjusted yields, obtained for materials resulting in effective control, show some increase in yield over the check but the differences are not as striking as in 1950.

1951 Demonstration Tests with Heptachlor.—Early in July, 1951, with the cooperation of the Extension Service, a single $\frac{1}{4}$ acre plot of peanuts was dusted with 5% heptachlor at the rate of 30 to 40 pounds per acre, in each of the eight counties in the main peanut growing area of northeastern North Carolina. Treated plots were one stack row wide (7 to 10 rows) and from 300 to 519 feet long. The adjacent untreated part of the field was used as a check plot in each case. No attempt was made to select fields which might be favorable for rootworm infestation.

Counts were made August 28 and 29, 1951, by examining the mature and immature pods on 10 plants pulled at random from treated and adjacent untreated areas. The percentage of injured pods in treated plots ranged from none to 12.7 per cent with a mean of 2.9 per cent. In the plot with the highest per cent of injury part of the injury at least was done by wireworms of the genus *Melanotus.* In the treated plot with the second highest per cent of injury, some of the injury was due to larvae of the elongate flea beetle, *Systena elongata* (F.). The percentage of injured peanuts in the untreated plots ranged from 20.7 to 65.5 per cent with a mean of 37.0 per cent.

1951 TASTE TESTS.—Taste panels were run with 13 lots of oil-cooked peanuts and 13 lots of peanut butter prepared from samples submitted to the Federal Bureau of Plant Industry. Peanuts so tested were from plots treated with aldrin (2 lbs./A), dieldrin (1 lb./A), heptachlor (2 lbs./A) and chlrodane (4 lbs./A) and from untreated plots.

Table 3.—Results of taste tests with oil-cooked peanuts and peanut butter, 1951.

Treatment	Toxicant P/A	Oil-Cooked Peanuts Score	Oil-Cooked Peanuts Rank	Peanut Butter Score	Peanut Butter Rank
Heptachlor (5% dust)	2	18.0	1	24.0	7.5
Aldrin (2½% dust)	2	19.5	2	22.8	4
Dieldrin (25% WP) in fert.	1	22.0	3	26.0	12
Heptachlor (25% WP) in fert.	2	23.0	4	24.2	9
Aldrin (25% WP) spray	8	23.5	5.5	26.0	12
Check	—	23.5	5.5	26.0	12
Check	—	24.0	7.5	22.5	2.5
Check (13 plus 35)	—	24.0	7.5	22.5	2.5
Dieldrin (25% WP) spray	1	24.5	9	24.0	7.5
Aldrin (25% WP) in fert.	2	26.0	10.5	23.0	5.5
Dieldrin (1% dust)	1	26.0	10.5	25.5	10
Heptachlor (25% WP) spray	2	26.5	12	23.0	5.5
Chlordane (50% WP) spray	4	31.5	13	22.0	1
L.S.D. (.05)		8.1		5.4	
(.10)		6.6		4.4	

In the taste tests each judge was given three samples and asked to rank them as to preference—if any. Three lots of material from check (untreated) plots were included in the 13 lots sampled, both as a check on the technique and consistency of the judges. Two complete sets of judges were used on the oil-cooked nuts and four complete sets of judges on the peanut butter. Each set consisted of 28 people and each treatment was compared with every other treatment once in each set with each treatment tasted by 6 people in each set. An analysis of variance of the treatment scores by Monroe of the Institute of Statistics shows little evidence that the insecticides produced undesirable flavors (Table 3). There was some evidence that oil-cooked peanuts from plots sprayed with chlordane (4 lbs./A) were rated down.

The data presented shows some interesting inconsistencies between the ratings of the same material as oil-cooked nuts and as peanut butter. This has been noticed in other years, also, when peanuts rated as tasting the best as oil-cooked nuts were sometimes rated as off-flavor when made into peanut butter.

SUMMARY.—Three years' work with soil insecticides, soil fumigants, and insecticidal dusts and sprays for the control of the southern corn rootworm, *Diabrotica undecimpunctata howardi* Barber, is reviewed. Benzene hexachloride, 1 lb./A; lindane, 1 lb./A; chlordane, 2 lbs./A and 4 lbs./A; aldrin, 2 lbs./A; dieldrin, 1 lb./A; and heptachlor, 1 to 2 lbs./A all gave good to excellent control. With all materials except chlordane the method of application made little difference in the control affected. DDT dust at 3 and 6 lbs./A gave control under conditions of light infestation but gave poor control where infestations were heavy. In some tests yield increases of nuts from 600 to 800 pounds per acre resulted from rootworm control.

Results of taste tests indicate that benzene hexachloride imparts an undesirable flavor both to oil-cooked peanuts and to peanut butter and that lindane causes off-flavor in peanut butter. There was evidence that chlordane (used as a spray at 2 lbs. or 4 lbs./A) may cause off-flavor in oil-cooked nuts but not in peanut butter. In one case only, there was some evidence of off-flavor in oil-cooked peanuts from plots treated with 2 lbs./A of heptachlor in a fertilizer mixture No off-flavor was detected in other taste tests of peanuts or peanut butter from heptachlor-treated plots and no off-flavor was noticed in peanuts or peanut butter from either aldrin, DDT or dieldrin treated plots.

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Cattle Lice Control by Clipping[1]

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Partial clipping of cows during the winter months has been a recommended practice as an aid to the production of clean milk. Hird *et al.* (1948) reported that partial clipping reduced bacterial counts in machine and hand drawn milk. Price & Allen (1948) demonstrated that clipping the entire body resulted in lower cardiac and respiratory rates. It was also observed by Price *et al.* (1949) that lice infestations appeared to be lower on clipped animals than on unclipped animals housed in the same pen. The effect of clipping on lice populations was further investigated during the winters of 1949–50 and 1950–51.

Procedure.—Experiments during both years were made on a herd of yearling heifers in which Holsteins were predominant, with smaller numbers of the other dairy breeds. During the 1949–50 experiment all of the animals ran together without segregation in a barn and an adjacent exercise lot. They were stanchioned only during feeding and examination periods. During the 1950–51 experiments, the clipped animals were segregated from the unclipped by housing on opposite sides of the barn with no opportunity for direct contact.

Three types of treatment as regards clipping were used. Part of the heifers were not clipped. They served as controls. Part of the heifers (referred to as whole clipped) were completely clipped, using an electric clipper with a lower blade of 0.09 inch thickness. Within this group, sub-groups were clipped at different times during the fall and winter. The third treatment applied to a part of the heifers (referred to as half-clipped) was to clip the entire right half of the body, leaving the left side unclipped. This gave a within-animal comparison.

Examinations for lice were made at weekly intervals. The examiner used a head lamp and a pair of stereoscopic spectacle magnifiers. Population counts were made over a 12-inch strip starting at the shoulder and extending along one side of the top-line, past the hip and over a portion of the thigh. The hair was parted with the fingers, and an actual count made over the entire counting area during an interval of 4 minutes. By this procedure, only a sample of the infestation was taken rather than a total count of a particular concentration or colony. On the unclipped check and whole clipped animals, counts were made on the right side only. Half-clipped animals were examined on both sides. The chewing louse, *Bovicola bovis* (Linn.) was the dominant species infesting all animals in this study. Only occasional small colonies of the sucking louse, *Solenopotes capillatus* Enderlein, were found.

1949–50 Studies.—During the 1949–50 studies, the herd was divided into six lots. Three lots were completely clipped at the following time intervals. One lot was clipped during the first week in December (2 months prior to peak louse infestation). The second lot was clipped on January 7 (1 month prior to peak infestation). The third lot was clipped on February 23 (at peak louse infestation). Two additional lots were clipped on the right side of the body, one early in December, the other on February 23. Although all animals were run together, providing ample opportunity for infestation, there were wide differences in population counts between animals (Table 1). Consecutive counts on an individual animal, however, were very uniform. Holsteins with their longer, coarser hair generally were more heavily infested than the Jerseys or Guernseys, but there was wide individual variation within breeds. Sample population counts at peak concentration on Holsteins, for example, ranged from 280 to 14. Within breeds, the longer, coarser haired animals were usually most heavily infested.

Counts on the check group indicated that infestations increased rapidly during the latter part of January, apparently reaching a peak during the first two weeks in February (Fig. 1). Unfortunately, two successive weekly counts were omitted during this period, which obscured the actual peak, although a peak infestation was clearly demonstrated for other groups. During the latter part of February, populations declined as rapidly as they had

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Table 1.—Relative population counts on unclipped (check) animals (1950).

Herd Number[1]	January			February		March				April				May			
	14	23	28	18	25	6	13	23	29	3	11	19	25	10	17	22	29
45 J	2	38	41	29	0	10	14	12	10	8	0	0	0	0	0	0	0
49 J	8	12	10	7	12	0	3	0	0	0	0	0	0	0	0	0	0
51 G	6	12	14	5	0	34	18	10	8	0	0	0	0	0	0	0	0
60 G	0	7	11	15	12	21	30	18	13	9	10	8	0	0	0	0	0
224 H	53	47	51	150	24	38	24	18	19	21	125	76	12	0	0	0	0
231 H	67	154	169	147	131	83	61	38	24	18	20	6	0	0	0	0	0
276 H	97	94	91	54	23	14	25	19	14	10	12	12	8	0	0	0	0
280 H	151	150	156	107	92	98	102	0	0	0	0	7	0	0	0	0	0
285 H	6	10	14	27	0	12	10	0	0	0	7	0	0	0	0	0	0
Average	43	58	62	60	33	34	32	13	10	7	19	12	2	0	0	0	0

[1] Letter designations refer to breed: J, Jersey; G. Guernsey; H, Holstein.

increased. A more gradual decrease was observed during March and April until the average counts had reached zero early in May.

The results of complete clipping at various intervals before the normal peak infestation are illustrated by figure 1. On animals clipped in December, louse populations were very low during January and Feburary compared with the check group. A gradual build-up was observed during these months until infestations reached their maximum by the middle of March. This maximum persisted through April, but decreased rapidly during the latter part of May. Population recovery for animals clipped one month prior to the normal peak infestation followed a similar pattern, but at a much lower level than for animals clipped in December. Louse population recovery was negligible throughout the remainder of the season for the group clipped at peak population. These data indicate that a single clipping gives adequate louse control for a period of approximately two months. Temperature apparently was not the determining factor in the cycle of population, since clipping delayed a peak incidence of lice to a time when the population was declining rapidly on the unclipped controls, and prolonged their incidence for a considerably longer period of time. During preliminary trials in 1948, a number of animals were re-clipped when the louse population had recovered following the initial clipping. In all cases, this re-clipping showed the same effectiveness as the original in eradication of the lice (Price *et al.* 1949).

By clipping only one side of an animal, the unclipped side served as a control for the clipped area with all factors except clipping identical. There was no indication that migation of lice from unclipped to clipped areas, or vice versa, occurred to a degree which appreciably affected the results. On the unclipped sides, population trends were very similar to those of the unclipped control animals

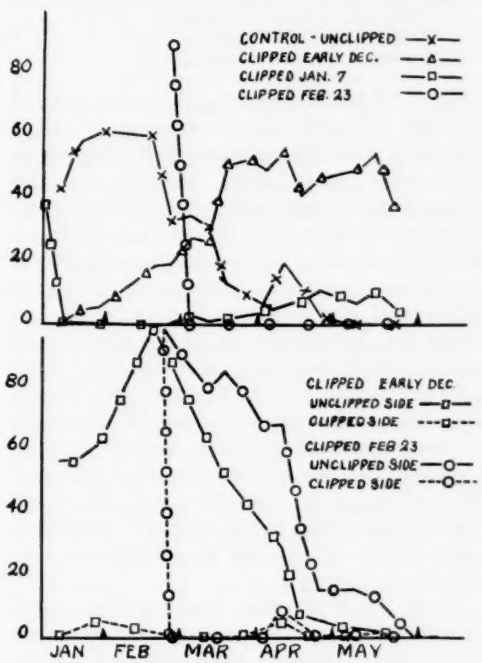

FIG. 1. Average louse population counts as influenced by clipping, 1949–'50 season.
Upper graph:
Control—Unclipped, average 9 animals.
Clipped early December, average 11 animals.
Clipped Jan 7, average 4 animals.
Clipped Feb. 23, average 8 animals.
Lower graph:
Half-clipped early December, average 8 animals.
Half-clipped Feb. 23, average 8 animals.

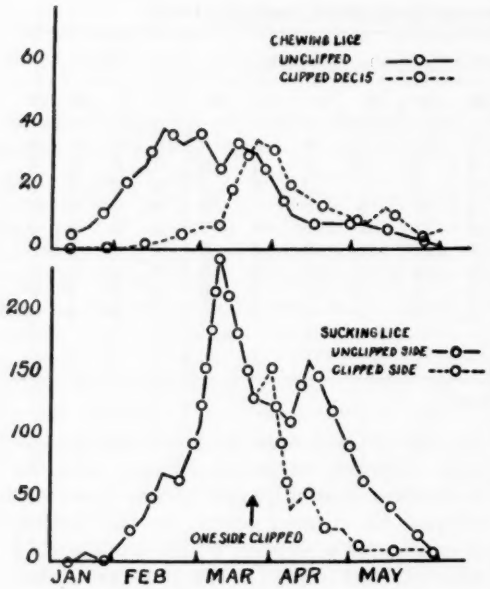

FIG. 2. Average louse population counts as influenced by clipping, 1950–'51 season.
Upper graph:
Unclipped, average 24 animals.
Clipped, average 21 animals.
Lower graph: Average 3 animals.

(Fig. 1). Lice were brought under control on the clipped side immediately after clipping. On the animals half-clipped in December, population samples on the clipped sides were reduced within a week from an average of 56 lice per animal to an average of one, while the population on the clipped side was unchanged. One day after half clipping the February 23 lot, there was an average of 93 lice per animal on the unclipped side as compared to 0.8 lice per animal on the clipped side. Populations on the clipped sides of the half-clipped animals did not recover to the extent that they did for the whole-clipped lot. There is a need for more work on the fundamental causes for the spontaneous decline of the lice population in late winter and spring.

1950–51 STUDIES.—During the winter of 1950–51, the clipping experiments were continued. During the previous years, following clipping, the heifers intermingled freely with the unclipped animals, providing ample opportunity for re-infestation. Under these conditions, a single clipping in late fall did not control the lice through the entire season, but merely delayed the build-up. A second clipping in early February was required for complete control. Since the clipped heifers were continuously exposed to infested animals, the build-up may have come from re-infestation from the unclipped heifers. Without this source of re-infestation, there remained a possibility that one clipping might give effective control throughout the winter. During the winter of 1950–51 the herd of 50 heifers was divided into two groups housed on opposite sides of the barn with no opportunity for direct contact. All of the heifers of one group were clipped December 15. Those of the other group were not clipped.

Results of this study are summarized by figure 2. Peak populations of the chewing louse in the unclipped group were observed during a period extending from the middle of January until the second week in February. Although louse populations reached a peak earlier than in 1949–50, the rapid decline (latter part of February) was comparable for the 2 years. On the clipped animals, the average louse population remained at a negligible level until February 10, when a rapid increase to the peak occurred. This peak also occurred at an earlier date than for the 1949–50 studies, although the populations decreased more rapidly and were comparable during the latter part of May with the average counts on check animals. It is apparent from these observations that there are sufficient reservoirs of infestation on the animals themselves to permit the population recovery, and that a single clipping in early winter is not sufficient to control lice throughout the season. The observations on clipping at different times and on re-clipping indicate that one clipping in early winter and another in late February should give very effective control of the chewing louse.

Infestations of the sucking louse, *Solenoptes capellatus*, were negligible in the unclipped group of the 1950–51 experiments. In the group entirely clipped on December 15, an appreciable population developed on three animals (Fig. 2). Populations reached a principal peak infestation on February 19, with a lesser peak one month later. On March 3, the left sides of these animals were reclipped. Subsequent counts on both sides indicated that the infestation in the clipped side was appreciably reduced and did not recover for the remaining period of the ex-

periment. While the population of sucking lice was substantially reduced by clipping, the degree of control was not nearly as complete as that of the chewing lice.Moreover, the original build-up of sucking lice occurred during a period when the chewing lice had been practically eradicated by clipping.

DISCUSSION.—Clipping the hair coat of heifers infested with chewing lice reduced the louse population to a very low level within a matter of hours. The lice were not removed in appreciable numbers with the hair, but were observed clinging to the short stubs of hair near the skin following clipping. Nits also remained on the hair stub. No evidence was secured as to the cause of the disappearance of the lice following clipping. Exposure to lower temperatures is a possible factor, but the effect of clipping seemed to follow the same pattern on warm days as during the coldest weather. This suggests that the results did not come about entirely through exposure of the lice to lower temperatures.

The individual differences in susceptibility of unclipped animals are also very striking. There seemed to be a general relationship to the texture of the hair. The heifers with long, coarse hair tended to show the heaviest infestations, while animals with soft, fine hair were practically free of lice, although they ran in the same barn and lots. The population cycle which occurred on unclipped animals is also striking, particularly the spontaneous decline during late winter.

Further work is planned on the environmental and nutritional requirements of the chewing louse to secure information on the reason for their disappearance following clipping, for the characteristic population cycle and for individual differences in susceptibility of cattle.

The sucking lice were not affected by clipping to as great a degree as the chewing lice. On three animals, large populations of sucking lice built up during the period following clipping when the heifers were practically free of chewing lice. A reclipping of one side of these heifers reduced the population of sucking lice, but not to a degree comparable with the characteristic reduction of chewing lice. The sucking lice appeared to be much less sensitive to environmental differences due to clipping, and to be able to thrive where the chewing lice did not increase.

A single clipping in late fall does not appear to be adequate for control for the entire season. The animals seem to retain enough lice, perhaps in protected areas, to re-infest them when the environment becomes more favorable. Based on these observations, it would appear that a late fall clipping, followed by re-clipping about February 1, should give practically complete control.

Heifers clipped on the coldest winter days suffered no ill effects.

SUMMARY.—Louse population studies on young dairy stock over a period of two years under Wisconsin conditions demonstrated that infestations of the chewing louse increased rapidly during the latter part of December, reaching a peak infestation by early February. By the latter part of February, populations were observed to decrease rapidly with a subsequent gradual decline during March and April and a comparative absence by the first of May. A wide range of individual susceptibility to louse infestations was evident.

Clipping appears to be an effective means of control for the chewing louse. Re-establishment of heavy infestations on animals clipped early in the season, however, may occur, and these infestations may be prolonged beyond the normal seasonal incidence. These studies indicate that in Wisconsin an initial clipping in late fall or early winter, followed by a second clipping during the first part of February, should bring the chewing louse under satisfactory control.

Limited observations indicated that clipping does not control the sucking louse as effectively as it controls the chewing louse, but that it does reduce the population substantially.

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New Materials in Early Sprays for Control of Brown Almond Mites

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Growers of almonds and peaches are often preoccupied at the start of the growing season with spray operations required for portection against infestations of fungi (*Sclerotinia* and *Coryneum*), peach twig borer *Anarsia lineatella* Zell., and brown almond mite, *Bryobia praetiosa* K. Since these dissimilar organisms require attention at or about the same time, it often would be expedient to combine the controls in one pre-bloom spray. Because of the difficulty experienced in controlling the mites for long periods with near-bloom sprays, growers heretofore have found it necessary to make at least two applications for the three classes of pests. An exception is the practice adopted by some growers of adding copper fungicides and lead arsenate to dormant oil sprays; a few sometimes apply this mixture as late as the pink-bud period.

The development of a more flexible, multi-purpose spray requires an effective acaricide which will function well when used in conjunction with the grower's choice of copper fungicides, and with basic lead arsenate or DDT. A principal objective in this work has been to examine the tendencies of new acaricidal materials when applied in spray operations usually needed for other pests. Other incidental purposes have been served by trying some of the sprays listed in the tables.

In exploratory try-outs the first of the organic miticides to show special promise of fulfilling the requirements outlined above was p-chlorophenyl p-chlorobenzenesulphonate (K-6451).[1] Subsequent tests were extended to include related materials, some of which were tried in various combinations likely to fit local orchard practices.

Procedure.—The techniques employed in these tests differ considerably from those often used in control work on red spider mites.

Measurement data were taken only once after the treatments were applied. The over-wintered eggs hatch in greatest numbers during the period of petal drop and infestations thereafter slowly increase to a peak or crisis during the latter part of May or early June. It was therefore practical to evaluate different treatments, or similar treatments applied at different times, in terms of ultimate or residual effects on the mite populations at or near the peak of the attack.

The test plots for which numerical data are given were manually sprayed with high pressure rigs operating at 400 psi.

The sampling procedures applied to the almond plots are based upon numbers of mites recovered from relatively uniform bits of foliage cut at random from the periphery of the trees. Six twigs, each approximately 16 inches in length, were taken from each of 5 trees within a plot, or 30 twigs per sample per plot. The active mites were beaten from the twigs onto sheets of paper and fixed by crushing. Inequalities in the sizes of twigs were adjusted by relating numbers of mites recovered to numbers of shoots borne on each of the twigs, *i.e.*, mites per shoot. The numbers of mites crushed onto sheets 8.5×11 inches in area were often very great and tedious to count. It was advisable, therefore, to introduce a second sampling process by which only the mites on a portion of the sheet were counted. This was accomplished with the aid of a wheel-like template exposing only 5 square inches of the paper surface. In this manner the mite populations were finally measured in relative values called "ratios," *i.e.*, average numbers of mites per shoot per template. This procedure is described in greater detail elsewhere (Summers & Baker 1952).

For purposes of statistical consideration, the ratios obtained for samples of almond twigs from different plots are arranged in tables 1 to 5 according to increasing order of magnitude. The summary statements concerning the significance of differences between mean ratios taken two at a time are based on *t*-tests appropriate for samples of equal sizes but having very unequal variances, as indicated by Welch (1938) and applied to samplings of this kind by Summers & Baker. Comparison of samples two at a

[1] *Ovotran*, 50% wettable powder, Dow Chemical Co.

Table 1.—Results obtained with semi-dormant and pink-bud sprays applied to almond trees. Dunnigan, California, 1950.

Treatment Designation	Materials and Amounts per 100 Gallons of Spray	Total Nos. of Shoots and Mites per Template on 30 Twigs per Plot		Averages 30 Ratios per Treatment	Per Cent Control (Est.)
		Shoots	Mites		
A	Lime-sulphur (31° Baume) 10 gals.	790	25	0.03	100
B	Lime-sulphur 3 gals.+wettable sulphur 5 lbs.	576	24	0.04	100
C	Cr-1639 1 lb. 25% w.p.	685	31	0.05	100
D	DN-289 2 qts.	761	162	0.25	98
E	K-6451 2 lbs. 50% w.p.+DDT 2 lbs. 50% w.p. +Copper-A 4 lbs.+oil 1.5 gals.[1]	516	181	0.33	97
F	Lime-sulphur 3 gals.	535	271	0.55	95
G	K-6451 2 lbs. 50% w.p.	588	301	0.67	94
H	Dormant oil emulsion[1] (80%) 4 gals.+DDT 2 lbs. 50% w.p.	728	964	1.27	88
I	88-R 1 lb. 15% w.p.	533	994	2.15	80
	3 check plots (averages)	512	4857	10.53	—

Treatments A, D and H applied February 9, 1950 (semi-dormant); others applied February 23 (pink-bud). Plots sampled May 11–13. Volume of sprays approximately 100 gals. per 8 trees per plot. Varieties: Peerless, NePlus, Drake; planted 48 trees per acre. Differences between ratios of any two treatments listed adjacently are not significant. Ratios of treatments A and E differ at 5% level; E and I differ at 1% level.

[1] Ortho Kleenup Flowable, California Spray-Chemical Corp.

Table 2.—Results obtained with pink-bud sprays applied to almond trees. Dunnigan, 1951.

Treatment Designation	Materials and Amounts per 100 Gallons of Spray	Total Nos. of Shoots and Mites per Template on 30 Twigs per Plot		Averages of 30 Ratios per Treatment	Estimate of Per Cent Control
		Shoots	Mites		
A	G-923 2 plots. 50% e.c.+Boredeaux+Multi-film L[1] 3 oz.	359	2	0.00	100
B	G-923 2 pts. 50% e.c.+Genicop 4 lbs.+oil 1 gal.	310	4	0.01	100
C	G-923 2 pts. 50% e.c.+COCS 4 lbs.+lead arsenate 4 lbs.	629	6	0.01	100
D	G-923 1.5 pts. 50% e.c.	501	8	0.02	100
E	K-6451 2 lbs. 50% w.p.+Bordeaux+DDT 2 lbs. 50% w.p.+Multi-film L 3 oz.	673	7	0.02	100
F	K-6451 2 lbs. 50% w.p.+Copper-A 4 lbs.+lead arsenate 4 lbs.+oil 0.5 gal.	611	25	0.04	99
G	K-6451 2 lbs. 50% w.p.+Bordeaux+lead arsenate 4 lbs.+S-1212[2] 2 oz.	661	40	0.05	99
H	G-923 2 pts. 50% e.c.+Genicop 4 lbs.	549	36	0.06	99
I	K-6451 2 lbs. 50% w.p.+Copper-A 4 lbs.+ DDT 2 lbs. 50% w.p.+Multi-film L 3 oz.	703	67	0.10	98
J	88-R 1 pt. e.c.+COCS 4 lbs.+lead arsenate 4 lbs.+oil 0.5 gal.	622	967	1.54	64
K	R-242 2 lbs. 40% w.p.+Genicop 4 lbs.	722	2123	3.06	29
L	R-242 2 lbs. 40% w.p.	471	1349	3.29	23
M	88-R 2 pts. e.c.+COCS 4 lbs.+lead arsenate 4 lbs.+oil 2 qts.	602	2176	3.78	12
N	MR-30 2 pts. 25% e.c.	698	2545	3.81	11
O	88-R 1 pt. e.c.+COCS 4 lbs.+DDT 2 lbs. 50% w.p.+Multi-film L 3 oz.	555	3192	6.11	0
P	88-R 2 lbs. 15% w.p.+COCS 4 lbs.+lead arsenate 4 lbs.	748	3304	5.04	0
Q	R-242 2 lbs. 40% w.p.+Bordeaux+DDT 2 lbs. 50% w.p.	576	3568	6.53	0
	6 check plots (averages)	647	2435	4.29	—

Treatments applied February 19 and 20, 1951. Plots sampled June 4–5. Volume of sprays approximately 90 gal. per 9 trees per plot. Varieties: Nonpareil, Peerless, Drake; planted 48 trees per acre. Treatments and 1 and 2 restricted to 3 trees each. Difference between the ratios of treatments C–I inclusive are not significant whereas all of these differ very significantly from the ratios of treatments J–Q. Ratios of I, J, and K differ at the 1% level.

[1] *Multi-film L*, spreader and deposit builder, Colloidal Products Corp.

[2] *S-1212*, depositor, Dow Chemical Co.

Table 3.—Results obtained with pink-bud sprays applied to almond trees. Woodland, California, 1952.

Treatment Designation	Materials and Amounts per 100 Gallons of Spray	Total Nos. of Shoots and Mites per Template on 30 Twigs per Plot		Averages of 30 Ratios per Treatment	Estimate of Per Cent Control
		Shoots	Mites		
A	K-6451 2 lbs. 50% w.p.+COCS 4 lbs.+oil 0.5 gal.	862	42	0.06	98
B	K-6451 1.5 lbs. 50% w.p.+COCS 4 lbs.+oil 0.5 gal.	743	63	0.10	96
C	K-6451 1 lb. 50% w.p.+COCS 4 lbs.+oil 0.5 gal.	693	153	0.26	90
	2 checks (averages)	681	1176	2.58	—
D	G-923 1.5 pts. 50% e.c.+COCS 4 lbs.+oil 0.5 gal.	757	6	.01	99
E	G-923 1.5 pts. 50% e.c.+Bordeaux	683	7	.02	98
F	G-923 1 ft. 50% e.c.+COGS 4 lbs.+oil 0.5 gal.	652	23	.05	96
G	K-6451 1.5 lbs. 50% w.p.+Bordeaux	627	59	.08	93
H	DN-289 1 pt.+COCS 4 lbs.	776	227	.31	73
	2 checks (averages)	669	708	1.13	—

Treatments applied February 22, 24, 1952; 100–120 gals. per 12 Nonpareil trees per plot. Plots sampled May 28. Differences between ratios of any two treatments listed adjacently within groups A–C and D–H inclusive are not significant; A and C, G and H differ at the 1% level; D and F, D and G differ at the 5% level.

Table 4.—Results obtained with sprays applied to almonds in the period of petal fall. Esparto, California, 1951.

Treatment Designation	Materials and Amounts per 100 Gallons of Spray	Total Nos. of Shoots and Mites per Template on 30 Twigs per Plot		Averages of 30 Ratios per Treatment	Estimate of Per Cent Control (Est.)
		Shoots	Mites		
A	K-6451 2 lbs. 50% w.p.	444	9	0.02	99
B	G-923 1.5 pts. 50% e.c.+Multi-film L 3 oz.	513	12	0.02	99
C	Lime-sulphur 1 gal.+wettable sulphur 5 lbs.	560	75	0.14	96
D	Colloidal sulphur paste[1] (70% S) 4 lbs.	617	260	0.45	87
E	88-R 2 pts. e.c.	483	233	0.47	87
F	MR-30 2 lbs. 25% w.p.	567	632	1.14	68
G	Medium oil emulsion[2] (83%) 1.5 gal.+lead arsenate 4 lbs.	517	609	1.17	67
H	TEPP 0.5 pt. 20%+wettable sulphur 5 lbs.	537	744	1.40	61
I	R-242 2 lbs. 40% w.p.	472	727	1.45	59
J	Wettable sulphur (95% S) 5 lbs.	629	1225	1.77	50
K	Medium oil emulsion 1.5 gal.	434	877	1.94	45
	2 check plots (averages)	487	1608	3.55	—

Treatments applied March 12, 1951. Plots sampled May 28–29. Volume of sprays approximately 90 gals. per 9 trees per plot. Varieties: Nonpareil, NePlus, Drake; 48 trees per acre. Treatments A and B indistinguishable; B and C differ significantly at the 5% level; C and D, E and F differ at the 1% level.

[1] *Magnetic 70*, sulphur paste, Stauffer Chemical Co.

[2] *Orthol-K* Medium, California Spray-Chemical Corp.

time is cumbersome for large arrays. Of necessity, therefore, only the more pertinent comparisons were attempted; in general the poor treatments were disregarded.

The sampling procedure outlined above is not serviceable for estimating mite populations on peach trees. Appraisals of treatments to peaches are based on total numbers of mites counted on 100 selected peach leaves picked and examined one at a time.

RESULTS IN GENERAL.—Sulphonate Acaricides.—In these experiments the acaricides referred to as K-6451 and G-923[2] were found to be outstanding for use in conjunction with worm and fungus controls applied before bloom or in combination with worm controls applied after bloom. The pink-bud or popcorn copper sprays are almost universally used on almonds and are frequently used for

[2] *Genite EM-923*, 50% emulsifiable concentrate, General Chemical Division Allied Chemical and Dye Corp.

Table 5.—Results obtained with sprays applied to almonds in late April. Arbuckle, California, 1951.

Treatment Designation	Materials and Amounts per 100 Gallons of Spray	Total Nos. of Shoots and Mites per Template on 30 Twigs per Plot		Averages of 30 Ratios per Treatment	Estimate of Per Cent Control
		Shoots	Mites		
A	G-923 1.5 pts. 50% e.c.	549	2	0.00	100
B	K-6451 2 lbs. 50% w.p.	624	29	0.04	97
C	Lime-sulphur 1 gal.+wettable sulphur 5 lbs.	470	58	0.06	96
D	Colloidal sulphur paste[1] (70% S) 4 lbs.	686	49	0.07	96
E	Bentonite-sulphur[2] (81% S) 5 lbs.	533	43	0.10	94
F	TEPP 0.5 pt. 20%+wettable sulphur 5 lbs.	502	290	0.68	57
G	Wettable sulphur (95% S) 5 lbs.	643	551	0.83	47
	2 check plots (averages)	605	955	1.57	—
H	4049 1.5 pts. 47.7% e.c.	651	713	1.14	47
I	88-R 2 lbs. 15% w.p.	540	611	1.19	45
J	Medium oil emulsion 1.5 gals.	622	1357	2.19	0
K	R-242 2 lbs. 40% w.p.	514	1149	2.47	0
	Check plot	624	1149	2.16	—

Treatments applied April 24–25, 1951. Plots sampled June 4–5. Volume of sprays approximately 88 gals. per 8 trees per plot. Varieties: Texas, NePlus, Drake; 65 trees per acre. Differences between ratios of any 2 treatments listed adjacently not significant for treatments A to E inclusive. However, A and C, A and D, E and F differ at the 1% level.

[1] *Magnetic "70" sulphur*, paste, Stauffer Chemical Co.

[2] *Kolospray*, Niagara Chemical Division, Food Machinery Corp.

peaches to supplement or in lieu of the fall copper sprays. A limited range of dosages of both acaricides were tested through several seasons on the principal varieties of almonds (Ne Plus, Nonpareil, Peerless, Drake, Texas and I.X.L.) and on some varieties of peaches (Elberta, Paloro, Fortuna, Johnson and Lovell). Within the range of dosages and periods specified there have been, so far, no indications of phytotoxic effects.

The multi-purpose sprays included basic lead arsentae or wettable DDT and one of several copper fungicides, namely, Bordeaux (5-5-50 used throughout), Copper-A[3], COCS,[4] Zinc Coposil[5], "340" Spraycop,[6] and Genicop[7] (the latter containing DDT). Supplements of oil emulsion, wetting agents or deposit builders were included in some sprays to test compatibili-

[3] *Copper-A*, E. I. DuPont de Nemours and Co.

[4] *COCS*, Niagara Chemical Division, Food Machinery Corp.

[5] *Zinc Coposil*, California Spray-Chemical Corp.

[6,7] *"340" Spraycop, Genicop*, General Chemical Division, Allied Chemical and Dye Corp.

Table 6.—Results obtained with sprays applied to peaches in pink-bud and petal-fall periods. Modesto, California, 1952.

Treatment Designation	Materials and Amounts per 100 Gallons of Spray	Numbers of Mites on 100 Leaves	Estimate of Per Cent Control
A	G-923 2 pts. 50% e.c.+DDT 1 lb. 50% w.p.+Bordeaux 5-5-50	12	99
B	G-923 1 pt. 50% e.c.+DDT 1 lb. 50% w.p.+Bordeaux 5-5-50	72	93
C	K-6451 2 lbs. 50% w.p.+DDT 1 lb. 50% w.p.+Bordeaux 5-5-50	119	89
D	K-6451 1 lb. 50% w.p.+DDT 1 lb. 50% w.p.+Bordeaux 5-5-50	150	86
E	K-6451 1.5 lb. 50% w.p.+DDT 1 lb. 50% w.p.+Bordeaux 5-5-50	206	81
F	Lime-sulphur 5 gals.	726	33
	Check plot (DDT 1 lb. 50% w.p.+Boredeaux 5-5-50)	1083	—
G	K-6451 1.5 lbs. 50% w.p.	75	97
H	G-923 2 pts. 50% e.c.	110	95
I	Bentonite-sulphur[1] (30% S) 5 lbs.	1329	43
J	Lime-sulphur 0.5 gal.+wettable sulphur	1331	43
K	Bentonite-sulphur (81% S) 5 lbs.	1433	39
L	Colloidal sulphur paste (70% S) 4 lbs.	1572	33
	Check plot	2347	—

Treatments A–F applied in pink-bud, February 29, 1952; 110 gals. per 15 trees per plot. Treatments G–L applied in petal-fall, April 4; 80 gals. per 15 trees per plot. All Paloro variety, 90 trees per acre. Counts made on May 6 (before peak of attack).

[1] *Kolospray*, Niagara Chemical Division, Food Machinery Corp.

ties rather than refinements in control. No changes in the effectiveness of the sulphonate acaricides were detected when the fungicides or vermicides were included. Similarly, the presence of wettable K-6451 (also 88-R) in spray mixtures containing copper fungicides and DDT did not noticeably affect the action of the latter on populations of peach twig borer (Summers 1952).

Pink-bud sprays containing 50 per cent wettable K-6451 in the dosage range of 1.5 to 2 pounds per 100 gallons gave good to excellent results (Table 1: E, G; Table 2: E, F, G, I). Single applications before bloom kept almond foliage very clean throughout the entire period of attack. The untreated portions of the orchards at Dunnigan, California, were very heavily infested, such that all of the foliage was badly yellowed by mid-May. Somewhat less serious infestations were encountered in the tests at Woodland wherein three dosage levels were tried in adjacent plots (Table 3: A–C). In these plots, the 2-pound dosage was better than the 1-pound dosage; the latter was considered to be an "adequate" but not outstanding control. The intermediate, 1.5-pound dosage was difficult to distinguish from the upper and lower dosages.

As applied to peaches in the pink-bud (Table 6: C–E), sprays containing K-6451 did not produce the striking results as obtained with those applied to almonds. However, the volumes of spray per tree were lower in the peach plots, and the mite populations were estimated on a different basis. The results in this experiment were judged to be "fair" control, with no assured differentiation between dosage levels.

The 12 treatments listed in table 6 were duplicated in two other unrelated peach orchards. These were appraised only by inspection; there were no contradictory results, at least among the better treatments.

Pink-bud sprays containing G-923 (50 per cent emulsion concentrate) were applied to both almonds and peaches. In general the results were judged to be excellent for dosages carrying between 1.5 and 2 pints per 100 gallons (Table 2: A–D, H; Table 3: D, E; Table 6: A). Lower dosages of this acaricide were tested several times in measurement plots. In one test, the ratio obtained with 1 pint of G-923 applied to almonds was statistically distinguishable from only one of two plots receiving 1.5 pint dosages (Table 3: D, F). In another test, on peaches, a difference in the appearance of trees receiving 1 and 2 pints of this acaricide per 100 gallons were possibly discernible by inspection and by counts of the mites on samples of leaves (Table 6: A, B).

Petal-fall applications of K-6451 or G-923 functioned as effectively as sprays applied before bloom (Table 4: A, B; Table 6: G, H). However, the foliage injury produced by immature mites hatched during the period of bloom was evident for several weeks after sprays were applied.

Treatments with K-6451 or G-923 applied later than the period of petal-fall appeared to be slow to attain maximum effect. Although ultimate numerical results obtained with April sprays applied to almonds (Table 5: A, B) were as good as those from trees treated earlier in the season, the appearance of the foliage was different. The mite damage accumulating to date of treatment persisted thereafter. Benefits obtained with sprays applied as late as May 23 were of doubtful value because the period of natural population decline apparently intervened before maximum returns were realized from the sprays applied. Data on these May sprays are listed in an earlier paper (Summers and Baker).

Eggs of *Bryobia* treated with either of these two acaricides failed to hatch. Infested trees sprayed before the first hatch began produced very clean foliage. Twigs cut from such trees during the late jacket period showed deposits of eggs long overdue to hatch. Also dead larvae and nymphs were occasionally observed on treated wood.

The data given do not demonstrate very sharp contrasts between results obtained with 1.5 to 2 pounds of 50 per cent K-6451 and 1.5 to 2 pints of 50 per cent G-923. The small differences shown in the entire series of tests may be related to variations in coverage.

DINITRO PHENOL.—The triethanol amine salt of dinitro-o-sec. butyl phenol was tested on almonds in semi-dormant sprays, only one of which was appraised by the "squeeze sheet" sampling procedure (Table 1: D). The pronounced ovicidal

effect of this material on the eggs of the brown almond mite were first noticed in connection with sprays under test for value in control of peach twig borer (Summers 1952). The data in table 1 (D) show that two quarts of a commercial formulation (16 ounces active ingredient)[8] per 100 gallons applied 2 weeks before the pink-bud period gave an excellent result in mite control as determined approximately three months after treatment. A number of tests applied to almonds by growers were also observed to be very satisfactory from the standpoint of mite control. Whether or not sprays containing this material applied in the semi-dormant period eliminate the need for additional fungicide sprays was not determined. The observed applications were followed with Bordeaux sprays in the popcorn period.

Local field personnel concerned with chemical thinning of stone fruits by using sprays containing dinitro-phenol materials have tentatively concluded that such sprays also affect the populations of mites. An exploratory test of the acaricidal value of a low-dosage treatment (4 ounces active per 100 gallons) was attempted by using mite-infested almonds (Table 3: H). The observed ratio of 0.31, or 73 per cent reduction at crisis is only indicative however since a fixed copper was included in the spray and the date of application was advanced to the pink-bud in order to minimize thinning action. The latter is not desirable in the case of almonds.

LIME-SULPHUR AND SULPHUR.—Lime-sulphur or mixtures of lime-sulphur and wettable sulphur have been used for many years by orchardists for mite and disease control. Nevertheless, controversies still exist relative to amounts required and results obtainable in connection with infestations of brown almond mite.

When applied to almonds in certain localities (Arbuckle, in Colusa County; Winters, Dunnigan and Esparto, in Yolo County), high-volume sprays containing lime-sulphur have given results equivalent to those obtained with the best organic materials tested so far. The dosages of 10 gallons of lime-sulphur per 100 gallons in a semi-dormant spray or 3 gallons of lime-sulphur plus 5 pounds of wettable sulphur per 100 gallons applied to almonds as a pink-bud spray gave equally fine control. A trial of 3 gallons of lime-sulphur alone was perceptibly poorer (Table 1: A, B, F). Good control was also obtained with a petal-fall spray containing 1 gallon of lime-sulphur plus 5 pounds of wettable sulphur (Table 4: C). This mixture applied in the early petal-fall period, prior to the peak hatch of over-wintered eggs, kept the foliage relatively free of mite injury thereafter. However, there were slight symptoms of leaf burn on tender shoots in this particular trial. A later application of the 1 plus 5 mixture (Table 5: C) was slow to reduce the mite population to a similar low level.

Sprays containing colloidal sulphur paste or colloidal bentonite-sulphur, as used in post-bloom periods, proved to be significantly better than sprays containing a higher percentage of ordinary wettable sulphur (Table 4: D, J; Table 5: D, E, G). Single applications of sprays containing 5 pounds of wettable sulphur per 100 gallons did not adequately control heavy infestations.

The addition of TEPP to wettable sulphur sprays applied during the early period of mite build-up did not make an appreciable difference in the long run (Table 4: H; Table 5: F).

Other experimental and commercial tests of these sulphur materials were made during the past 3 years in two of the principal peach-growing districts of Central California (Wheatland, in Sutter County; Modesto and Empire, in Stanislaus County). Sprays containing various amounts of lime-sulphur, sulphur or mixtures of the two materials did not give acceptable control of brown almond mites on peaches in the localities mentioned above. Poor responses to sulphur sprays, such as those recorded in the peach orchard sampled (Table 6: F, I–L), also obtained in nearby almond orchards.

OTHER MATERIALS.—Experimental lots of several other new promising acaricides were tested on developing populations of *Bryobia*. One of these, Cr-1639,[9] appeared to be outstanding for use on almond trees. A sample drawn from one of the test plots gave results shown in Table 1 (C). Various dosages of 88-R[10,11] produced variable results the best of which was judged to

[8] *DN-289*, Dow Chemical Co.
[9] Cr-1639, *Karathane*, 25% wettable powder, Rohm and Haas Co.
[10] 88-R, *Aramite*, 15% wettable powder, U. S. Rubber Co.
[11] 88-R, *Niagaramite*, emulsion concentrate, 4.8 lbs. active ingredient per gallon, Niagara Chemical Division, Food Machinery Corp.

be "acceptable" control (Table 4: E), and the poorest of which gave no appreciable reduction of the mite population (Table 2: P). Combinations containing 88-R and oil emulsion showed mild phytotoxic tendencies.

Preliminary tryouts of experimental formulations of R-242,[12] MR-30,[13] or 4049[14] were not sufficiently encouraging to warrant further trials under similar conditions.

DISCUSSION.—The task of effectively reducing to trace level the heavy populations of brown almond mites, as frequently encountered in almond-growing sections, requires an appreciation of the problem of spraying the "hidden fraction" of the mite population. This species is essentially a bark-inhabitaing species. Most of the eggs are deposited on the woody portions of the host trees. During the growing season the mobile forms make daily excursions to feed on leaves when conditions are favorable; otherwise they tend to congregate and oviposit on the undersides of the branches, in deep surface irregularities, in bark curls, cracks, cavities, and other locations difficult to cover with sprays.

The miticides appearing to be most effective in the near-bloom period are those which function chiefly as ovicides or larvicides and which are sluggish in their action against adult mites. Materials of this general type give best results in "soak the wood" types of applications. The failures or near-failures observed in commercial tryouts were those in which the framework of the trees, including trunks, were not thoroughly wetted.

Almonds present no major issue in regard to active residues because the nuts are hulled and often shelled before entering trade channels. The matter of possible flavor alteration of nuts receiving treatments with the sulphonate acaricides was examined on the basis of sample nuts taken from plots sprayed by the writer during 1951. In one test, trees of the Texas variety were sprayed on June 19, 101 days before harvest. Samples of nuts were taken from one plot sprayed with G-923 at the rate of 1 gallon of 50 per cent emulsion concentrate per acre, and from another sprayed with K-6451 at the rate of 8 pounds of 50 per cent wettable powder per acre. In another test, G-923 and K-6451 were applied to Nonpareil trees at the above rates on June 19, 78 days before harvest. Flavor tests covering the two acaricides on the two varieties were conducted by Dr. Elly Hinreiner, Department of Food Technology, University of California at Davis. As regards flavor, there were no significant differences between any of the treated nuts and their corresponding controls. It should be noted that the flavor tests apply to nuts sprayed in June, or later than the period during which these acaricides appear to be maximally effective for use on infestations of the brown almond mite. Information about the flavor of peaches sprayed with K-6451 or G-923 is not yet available.

SUMMARY.—It is often desirable to couple brown mite control with the spray operations ordinarily required in late winter to control shot-hole and brown rot fungi or the peach twig borer. In order to make this tie-in feasible the acaricides should effectively control the mites when included in pink-bud or petal-fall sprays. It should also be compatible with the growers' choice of copper fungicide and basic lead arsenate or DDT. A main objective of this work was to examine these attributes of new acaricides when applied to almonds and peaches. In the experiments described, materials and combinations of materials were appraised only in respect to effects on populations of the brown almond mite. The densities of the mite populations on almonds are expressed in relative terms called ratios, *i.e.*, average numbers of mites per shoot per template.

Single applications of G-923 and K-6451 proved to be very effective when used in full volume sprays applied prior to heavy build-up of the mite populations. Several seasons of experimentation with these sulphonate acaricides have shown that both are well-adapted for use in multipurpose sprays. Comparative data are given for a variety of pink-bud and post-bloom sprays containing one or the other of these. The experimental techniques employed in field work were not sufficiently sensitive to justify a conclusion as to which is the better acaricide. Taste tests revealed that there were no significant differences between samples of untreated

[12] R-242, *Sulphenone*, 40% wettable powder, Stauffer Chemical Co.

[13] MR-30 Experimental Material, 25% emulsion concentrate, also 25% wettable powder, Rohm and Haas Co.

[14] 4049 emulsion concentrate, 47.7% active ingredient, American Cyanamid Co.

nuts and samples of nuts which were sprayed in June with one or the other of these two materials.

Measurement data on two tests with a new dinitro phenol compound suggest that this insecticide has excellent possibilities for use in mite control. A semi-dormant spray containing 2 quarts of a commercial product (DN-289) gave an estimated 98 per cent control of a heavy mite infestation on almonds as determined approximately three months after treatment. A smaller dosage, such as used in blossom thinning sprays, also appeared to have considerable acaricidal value when tested in a pre-bloom combination on almonds.

Densities of residual mite populations were also determined for plots treated with several dosages of lime-sulphur, colloidal and ordinary forms of wettable sulphur. The responsiveness of infestations of brown almond mites to treatments with inorganic sulphur materials was found to differ between localities in which tests were made.

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Organic Phosphates as Systemic Insecticides on Pineapple Plants[1]

WALTER CARTER

The use of the organic phosphate insecticide, parathion, has become standard practice in Hawaii against the pineapple mealybug (*Pseudococcus brevipes* Ckl.). As a leaf spray, parathion is effective at low dosages, but shares with other leaf sprays the inability to reach and destroy colonies of mealybugs which may be established on the butts of the plants or on the base leaves below the soil surface. For control of such colonies, an effective systemic insecticide would be of great value. This paper describes some preliminary experiments on the use of parathion, systox, and malathon as contact and systemic insecticides for the control of the pineapple mealybug.

ORGANIC PHOSPHATES AS CONTACT INSECTICIDES AGAINST PINEAPPLE MEALYBUG.—Early tests compared HETP and TEPP with "compound 3422," as parathion was then called. The last named was so clearly superior that its use became standard practice after field-scale experiments had confirmed the laboratory tests. Parathion is therefore the standard with which new phosphates are compared.

Technique for laboratory testing is simple. Infested fruits are dipped and quickly withdrawn from the test suspension. After a period of several days the dead and living mealybugs are separated and counted. This technique, while possibly oversimplified, is more satisfactory than any automatic or even semi-automatic spray system tried thus far.

Sample results from such tests are presented in table 1.

PARATHION APPLIED TO THE SOIL PRIOR TO PLANTING.—In this field test, the parathion as 25 per cent wettable powder was sprayed over the soil surface and then hoed in, on October 28. The field was planted November 9. All the plants were grossly infested with mealybugs on May 9 by dropping a piece of infested fruit skin into the heart of each plant. One month later, the mealybugs were counted by careful inspection of the growing plants. There were six replications totalling 120 plants in each treatment, and the results are shown in table 2. There was no significant difference between any of the parathion treatments or between them and the untreated check.

SYSTOX APPLIED TO DETACHED PINE-

[1] Published with the approval of the Acting Director as a Technical Paper of the Pineapple Research Institute of Hawaii.

Table 1.—Mortality of mealybugs when infested fruits were dipped in parathion, malathon and systox at various dilutions.

Material	Dosage and Kill							
	1/800[1]		1/1600[1]		1/3200[1]		1/6400*	
	Dead	Alive	Dead	Alive	Dead	Alive	Dead	Alive
Parathion, 25% wettable powder	325	0	280	0	272	22	215	34
	300	0	172	2	124	0	97	30
	178	0	144	0	86	18	90	34
	175	0	111	1	75	1	53	5
	1/500[1]		1/1000[1]		1/2000[1]		1/4000[1]	
Systox, 50% emulsion	215	0	138	0	87	0	175	2
	336	0	124	0	115	0	74	0
	91	0	245	0	172	0	92	0
	142	0	259	0	188	0	119	0
	142	0	155	0	163	0	180	0
	1/500[1]		1/1000[1]					
Malathon, 25% wettable powder	98	0	176	5				
	128	0	101	5				
	132	6	138	6				
	147	1	183	8				
	118	1	133	3				
Malathon, 50% emulsion	176	0	210	16				
	210	0	132	4				
	185	0	266	3				
	183	0	223	7				
	291	7	118	6				

[1] Of formulation used.

APPLE LEAVES.—In these tests, median leaves from vigorously growing plants were pulled out and "painted" with a 1 to 500 dilution of systox. The systox was applied to the upper surface of the leaf on five leaves and to the lower surface of five leaves. In both cases, the lower third of the leaf was treated. Two hours later, 20 mealybugs were caged on the lower side of each of the leaves at or opposite the treated zone and also in similar positions on the untreated sections of the same leaves.

This technique therefore served to test (1) the residual toxicity of the chemical on the treated surface, (2) the absorption of the toxicant, and (3) the translocation of the toxicant. Counts of the live and dead mealybugs were made four days after treatment, and the results are shown in table 3.

In this test, there was at least a short residual effect on the actually treated lower surface ot the leaf, but no movement upwards from this zone. There was no effect on mealybugs fed on the lower surface when the opposite upper surface was treated, but there is some slight indi-

Table 2.—Survival of mealybugs on grossly infested plants treated with parathion at different dosages per acre.

Dosage (Actual parathion per acre)	Average Mealybugs per Plant 1 Month After Infestation (6 replications)						
Lbs.							Ave.
2.5	8.35	12.25	11.15	16.25	5.80	12.65	11.075
5.0	22.05	7.05	18.40	7.80	20.75	7.35	13.900
10.0	19.80	12.90	12.25	17.60	23.00	10.70	16.042
None	12.10	25.65	16.35	8.70	18.35	17.65	16.467

Table 3.—Survival of mealybugs treated with systox applied to the surfaces of detached pineapple leaves infested with 20 mealybugs per leaf.

PART OF LEAF TREATED	PART OF LEAF FED ON	NO. OF MEALYBUGS ALIVE AFTER 4 DAYS
Lower side of proximal end	Lower side of proximal end	0, 0, 5, 0, 2
	Distal end of same leaf	20, 17, 20, 15, 17
Upper side of proximal end	Lower side of same leaf opposite treated area	13, 16, 16, 15, 17
	Distal end of same leaf	9, 7, 16, 5, 15
Untreated	Proximal end	16, 18, 17, 18, 17
	Distal end	19, 20, 14, 19, 14

cation of movement of the toxicant upwards. Since any spray applied under field conditions would fall only on the upper leaf surface, this might have some significance.

This test was repeated with essentially the same results. It was repeated again, but with one series exposed to outside light for 24 hours before the leaves were infested. The exposed series showed negligible toxicity.

A field test in which mealybugs were caged on the more rapidly growing leaves one week after sprays of 1 quart, 2 quarts, and 4 quarts in 400 gallons water per acre were applied, and again one month after spraying, showed no significant mortality over the checks.

SYSTOX APPLIED TO THE SOIL BEFORE PLANTING.—In this test, plants were grown in boxes on benches in the open. There were 3 treatments, (a) D-D fumigated soil with no systox added; (b) systox added to the fumigant (D-D 95 per cent–systox 5 per cent) and applied after the soil had been boxed; and (c) systox solution applied to the mass of soil and thoroughly mixed before boxing. Systox was used in treatments (b) and (c) at the rate of 2 gallons/acre or 9.92 lbs. toxicant per acre.

The plants used were fresh, uninfested slips to each of which had been added 100 small to medium-sized mealybugs six days before the slips were planted in the boxes. The purpose of this technique was to simulate the field condition when infested slips are planted. The mealybug colonies initially established well but, as frequently happens with such colonies protected from ants, there was a gradual diminution in numbers, until 6 weeks after infestation the colonies had all practically disappeared.

The plants were growing vigorously by that time, however, and one median rapidly growing leaf was pulled from each plant. Twenty mealybugs were caged on each of these leaves and permitted to feed for a period of 10 days, when the cages were removed and the mealybugs counted. The results indicated a slightly greater mortality in the series from treatment (c), in which the Systox was mixed with the soil, but the difference was of no practical significance.

Table 4.—Survival of mealybugs on leaves and on underground stems of pineapple plants after being sprayed with systox at various dilutions.

	DOSAGES APPLIED IN 500 GALLONS WATER/ACRE														
	1 pint/acre					1 quart/acre					2 quarts/acre				
	Leaf colonies[1]					Leaf colonies[1]					Leaf colonies[1]				
SURVEY DATES	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
11/23/51	246	2	1	0	1	249	0	1	0	0	249	0	0	1	0
1/2/52	246	2	1	1	0	250	0	0	0	0	250	0	0	0	0
	Butt colonies[1]					Butt colonies[1]					Butt colonies[1]				
11/23/51	123	30	24	29	44	128	36	25	28	33	124	47	21	21	37
1/2/51	144	14	16	32	44	117	14	18	39	62	140	19	22	34	35

[1] 0=no mealybugs; 1=1–5 mealybugs; 2= 6–10 mealybugs; 3=11–20 mealybugs; 4=>20 mealybugs

Table 5.—Survival of mealybugs on leaves and on underground stems of pineapple plants after being sprayed with malathon at various dilutions.

Survey Dates	25% WP-8 Lbs./A					50% Emulsion-½ Gal./A					Checks				
	Leaf colonies[1]					Leaf colonies[1]					Leaf colonies[1]				
	0	1	2	3	4	0	1	2	3	4	0	1	2	3	4
11/23/51	245	1	3	1	0	248	1	0	1	0	107	50	36	37	20
1/2/52	244	6	0	0	0	246	2	2	0	0	95	63	39	33	20
	Butt colonies[1]					Butt colonies[1]					Butt colonies[1]				
11/23/51	142	44	18	14	32	108	36	21	37	48	90	23	31	41	65
1/2/52	153	16	18	29	34	149	12	18	21	50	80	25	28	37	80

[1] 0=no mealybugs; 1=1–5 mealybugs; 2= 6–10 mealybugs; 3=11–20 mealybugs; 4=>20 mealybugs

COMPARISON OF MALATHON AND SYSTOX AS CONTACT AND SYSTEMIC INSECTICIDES.—Laboratory tests of insecticides against mealybugs are useful in screening out the less promising compounds but can only be considered as preliminary to field tests. Because of the very variable distribution of *Pseudococcus brevipes* in the field, it is necessary that these field tests be extensive in both time and space.

In this test an infested field border approximately one mile long and 50 feet wide was selected. It was divided into plots 160 feet long to provide five replications of each of six treatments, including the unsprayed check. Three dosages of systox and one dosage each of malathon 25 per cent wettable powder and malathon 50 per cent emulsion wre used. All sprays were applied in *ca* 500 gallons of water/acre, three times at monthly intervals. Results were checked twice, first 11 days after the second spray had been applied and finally 12 days after the third spray. Sampling was done by pulling 50 plants at random from each plot, dissecting each plant and counting the mealybugs on the leaves and on the stump or below ground section of the plant. This division of the mealybug population served to separate the contact-spray effects from any systemic effect and to determine whether any effective translocation to the old stump tissue had taken place. The results are in tables 4 and 5, the check figures in table 5 being applicable to both tables.

As contact sprays, both systox and malathon at all dosages were satisfactory, but there was little if any effect on the sub-surface mealybug colonies.

The contact-spray results warranted residue tests, and these were conducted by the Chemistry Department of the Pineapple Research Institute for the malathon and by the Geary Chemical Corporation for the systox.

Leaf samples were taken 22 days after the second spray and again 17 days after the third spray from all the replicated plots. No malathon residue was detected either externally or internally. Systox residues reported by the Geary Chemical Corporation varied from 0 to 0.5 p.p.m. in the old leaves and from 0 to 0.1 p.p.m. in the youngest leaves.

DISCUSSION AND SUMMARY.—While all three phosphates (parathion, systox, and malathon) are toxic in greater or less degree to mealybugs as contact insecticides, it is clear that translocation, especially to the older portions of the plant, does not occur in toxic quantity. The conclusion is contrary to the results on many other crops.

One explanation offered accounts for this failure on the basis of the pH of pineapple leaf tissue which, early in the morning may be as low as pH 3.4. Stem tissue, however, is fairly constant at 5.2 $\pm$0.2. If the half life of these phosphates is greatly reduced under these pH conditions, that might well be a limiting factor.

Control of mealybugs on the underground portions of the plant is currently the most pressing problem, and a systemic insecticide suitable for use with the acidic soils and leaf tissue common to pineapple growing would be of great value.

Visible Reactions of California Red Scale in Relation to Resistance to Fumigation with HCN[1]

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The means by which the resistant California red scale, *Aonidiella aurantii* (Mask.), survives fumigation with hydrocyanic acid has been the basis for considerable discussion. Hardman & Craig (1941) concluded that the ability of this scale to keep its spiracles closed explains its resistance, but Quayle (1942) did not agree. A study was made during 1949 and 1950 to determine whether closure of that tracheae or other visible reactions of the California red scale were the cause of resistance.

Observations of individual scales were made during and after fumigation. Those during fumigation were made in an exposure cell in which the movements of the tracheae and the salivary pump were visible. Those after fumigation involved the behavior of a fluid with which the spiracles were covered. It was assumed that the tracheal entrances were open only if the liquid entered the tracheae. This procedure was used because the opening and closing mechanism could not be seen in operation. Before and after fumigation with hydrocyanic acid the oil immediately enters the spiracles and before fumigation it immediately enters the tracheae. The penetration of oil into the tracheae of California red scale has been described by deOng *et al.* (1927).

Nonresistant, resistant, and super-resistant scales (Yust *et al.* 1951) were observed. Nonresistant and resistant scales were obtained in the field in 1935 and had been reared in isolated compartments at the laboratory since that date. The super-resistant stock was obtained by repeated fumigation of resistant scales with sublethal dosages and propagating the survivors. The super-resistant scales had a history of 45 to 51 fumigations in the laboratory.

Gray adult scales of each stock were fumigated to determine whether there was a large difference in resistance to hydrocyanic acid in this stage. Each stock was exposed to five concentrations for 40 minutes at 77° F. The LD-95 was 0.12 mg. per liter for the nonresistant, 0.58 mg. for the resistant, and 1.55 mg. for the super-resistant stock, showing differences between the stocks in the gray adult stage about as large as in other stages (Yust *et al.* 1951).

The test scales of all stocks were reared on lemon fruits in the laboratory at a constant temperature of 77° F. Scales in the gray adult stage were used mostly, because various internal activities may be viewed through the body wall. In this stage the rostralis is inserted into the host material. In earlier tests the insects were detached from the host with the rostralis intact as described by Yust (1941). In most tests reported herein the insect body was lifted slightly and the rostralis clipped with small precision-ground scissors. Severing the rostralis did not influence the reaction of the scales. The observations were made with a compound microscope having a magnification of about 660×.

OBSERVATIONS DURING FUMIGATION.—The exposure cell for observations during fumigation was made from a block of Lucite 3 by 1 by 0.75 inches. All sides were ground smooth and polished. A chamber 0.5 inch in diameter and 0.125 inch deep was made on the wide side, and the bottom of the chamber was polished. A passageway was drilled lengthwise through the block to the chamber and connected by rubber tubing to the laboratory fumigation chamber (Yust & Howard 1943). The insect to be observed was placed ventral side down on a No. 1 cover glass having a thin coating of albumen fixative for adherence. The cover glass was then inverted over the cell chamber and sealed to the surface with petroleum jelly. Hydrocyanic acid gas of known concentration was aspirated through the cell while the insect was being observed.

Normally a vellicative movement, or pulsation, of the tracheae is apparent when California red scales, recently removed from host material, are viewed under sufficient magnification with transmitted light. The movement is most easily seen in the late gray adult, although it can be observed in other stages. The short, wide trunk connected to the spi-

[1] B.E.P.Q.Ms. 2028.

racle shows the strongest tie, and it occurs in nonresistant, resistant, and super-resistant scales. Normal pulsations in scales of all stocks ceased in about 1 minute when exposed to 1 mg. of hydrocyanic acid per liter. With other concentrations no difference between stocks was apparent. Operation of the salivary pump stopped at about the same time for the three stocks. The two positions of the inner structure of the spiracles, as reported by Hardman & Craig (1941), were not observed.

OBSERVATIONS AFTER FUMIGATION.—For the observations after fumigation five gray adults of each stock were placed dorsal side down on a 1- by 3-inch microscopic slide and attached with albumen fixative. The scales on the slides were exposed in the fumigation chamber to the desired concentration of hydrocyanic acid. About 1 minute after the exposure, unless otherwise stated, an 18-mm. No. 1 cover glass with a drop of special light petroleum oil (Cressman *et al.* 1950) was placed over the scales. The scales were observed up to 10 minutes after immersion, and the number of anterior tracheae taking oil was recorded as the number of open tracheae. The response of the tracheae in less than a minute after exposure was about the same as that 10 minutes later, and this applied following different exposure periods. The observations were restricted to the two tracheae associated with the anterior, or mesothoracic, spiracles, because the tracheae in this region were easier to see and in preliminary tests their reactions were the same as those of the two posterior tracheae. The reactions of 10 groups of 5 scales each, or 100 tracheae, were observed for each strain.

To determine whether tracheal closure is related to the resistance of California red scales to fumigation with hydrocyanic acid, tracheae of the three stocks were observed after exposures for different different periods. Scales were exposed to concentrations of 1 mg. per liter, and observations were made after exposures of 2, 4, 20, and 30 minutes. The percentages of the tracheae taking oil, or those considered to be open, are shown in table 1.

If closure of the tracheae causes resistance, it is assumed that it would do so by keeping out the hydrocyanic acid. Then during exposure most of the tracheae of the nonresistant scales would be open and most of those of the super-resistant scales would be closed. The tracheae of the resistant scales would show an intermediate condition. At the beginning of the exposure, as shown in table 1, most of the tracheae of the nonresistant scales were open, but after 30 minutes most of them were closed, whereas about half the tracheae of the resistant scales were open at each time observed. Most of the tracheae of the super-resistant scales were closed at the beginning of the exposure, and other data show that most were open 10 minutes after exposure began. Hence the tracheae of the super-resistant scales were open about as much as those of the nonresistant scales during a 40-minute period, and tracheal closure cannot be the explanation of resistance.

Table 1.—Percentage of mesothoracic tracheae of late gray adults of the California red scale which were open after various exposures to 1 mg. of hydrocyanic acid per liter.

EXPOSURE, MINUTES	NON-RESISTANT	RESISTANT	SUPER-RESISTANT
2	91± 4	41±6	18±4
4	94± 3	52±5	40±7
20	81± 9	65±6	86±5
30	34±10	57±6	84±7

It is of interest to note that the circulatory organ in nearly all scales of the three stocks was operating after exposure for 20 and 30 minutes to 1 mg. of the fumigant per liter. This indicates that death of the scales from hydrocyanic acid is not immediate.

Other tests were suggested by differences in reactions of the nonresistant and resistant strains to protective dosages observed by Lindgren (1938) and Yust (1942). Tracheal reactions of the three stocks were observed 1, 30, and 60 minutes after a 10-minute exposure to a stupefying dosage of 0.025 mg. per liter. It is unlikely that this dosage caused any mortality. In another test stupefaction with the same dosage was followed at intervals of 3, 30, and 60 minutes with a final 4-minute exposure to 1 mg. per liter. Observations were made immediately after the final exposure. The results are presented in table 2.

In these tests in table 2 there was little or no difference between the nonresistant and super-resistant scales 30 or 60 minutes after exposure to the stupefying dosage, but the resistant scales showed about the same or more open tracheae.

Table 2.—Percentage of mesothoracic tracheae of gray adults of California red scale that were open at various intervals after exposure to a dosage of 0.025 mg. per liter and immediately after the final exposure to 1 mg. hydrocyanic acid.

INTERVAL, MINUTES	NON-RESISTANT	RESISTANT	SUPER-RESISTANT
Stupefying dosage only[1]			
1	98±2	35±7	41±5
30	29±7	98±2	25±5
60	64±9	99±1	76±7
Stupefying dosage followed by final dosage[2]			
3	97±2	19±4	17±4
30	18±5	12±4	6±3
60	17±5	51±7	20±3

[1] Intervals between exposure to the stupefying dosage and observation.
[2] Intervals between exposure to the stupefying and the final dosage.

If closure causes resistance, we should expect little difference in kill between the nonresistant and super-resistant strains when fumigated under these conditions, but 60 minutes after the stupefying exposure, kill of the resistant scales should be the highest of the three strains. Accordingly, mortality tests were made in which the three stocks were exposed to a stupefying dosage of 0.025 mg. per liter for 10 minutes and after intervals of 30 and 60 minutes exposed to 0.46 mg. per liter for 40 minutes. The results were as follows:

STRAIN	PER CENT MORTALITY AFTER— 30 MINUTES	60 MINUTES
Nonresistant	71	85
Resistant	18	39
Super-resistant	4	4

It is evident that the order of susceptibility of the three strains was not changed by the conditions of this experiment and that tracheal closure cannot explain or be the cause of resistance.

These results do not agree with the assertions by Hardman and Craig (1941) that the spiracles of the nonresistant and resistant strains close in 3 to 5 minutes after hydrocyanic acid reaches them, nor do they support their idea that the spiracles of the nonresistant scales remain closed for about 1 minute and those of the resistant scales remain closed for 30 minutes. In these and other tests in which there was no stupefying dosage, most of the tracheae of nonresistant scales were open shortly after fumigation and were closed 30 minutes after fumigation. Most of the tracheae of the resistant scales were open 30 minutes after fumigation.

SUMMARY.—California red scales, *Aonidiella aurantii* (Mask.), that were nonresistant, resistant, and and super-resistant to hydrocyanic acid were observed to determine whether tracheal closure or other visible reactions to fumigation were the cause of resistance. Observations were made both during and after fumigation.

The tracheae of the three stocks reacted differently to the fumigant. Shortly after exposure began most of the tracheae of the nonresistant scales were open and most of those of the resistant and super-resistant scales were closed. As the exposure period increased, the tracheae of the nonresistant scales tended to close and those of the super-resistant scales tended to open. The results did not indicate that tracheal closure caused resistance, nor was there any other observed reaction that could account for resistance.

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Behavior of Octamethyl Pyrophosphoramide in Citrus Plants[1,2]

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The systemic insecticide octamethyl pyrophosphoramide, or bis-(dimethylamino)-phosphonous anhydride (OMPA), has shown valuable insecticidal properties for such citrus pests as the citrus red mite, *Paratetranychus citri* (McG.), and the citrus aphids *Aphis spiraecola* Patch & *Aphis gossypii* Glover. Against these pests, aqueous sprays containing from 0.5 to 2 pounds OMPA per acre have given highly effective control for periods of one to several months. Recently, a number of extensive and admirable studies on the behavior of OMPA in vegetable crops have appeared, namely, those of Ripper *et al.* (1950) and Wallace (1951), and of David (1951), who used material tagged with P^{32}. Little attention has been given to investigations of OMPA in tree crops, however, where problems of its practical use seem to demand intensive study. In the current investigation P^{32}-tagged OMPA has been employed with particular reference to its behavior in citrus plants, especially in the lemon, *Citrus Limon* (L.) Burm., the sour orange, *C. Aurantium* L., and the Valencia orange, *C. sinensis* (L.) Osbeck.

MATERIALS AND METHODS.—Technical OMPA has recently been shown (Hartley *et al.*, 1951) to be a mixture containing approximately 85 per cent phosphorus compounds extractable from alkaline solution by chloroform. These chloroform-soluble phosphorus compounds are listed below:

	Per Cent by Weight
I. $[(CH_3)_2N]_3P{=}O$	17.3
II. $[(CH_3)_2N]_2\overset{\overset{O}{\|}}{P}{-}O{-}\overset{\overset{O}{\|}}{P}[N(CH_3)_2]_2$	40.4
III. $[(CH_3)_2N]_2\overset{\overset{O}{\|}}{P}{-}O{-}\overset{\overset{O}{\|}}{\underset{\underset{N(CH_3)_2}{\|}}{P}}{-}O{-}\overset{\overset{O}{\|}}{P}[N(CH_3)_2]_2$	39.1
IV. $[(CH_3)_2N\overset{\overset{O}{\|}}{P}O]_2$	3.2

Constituents II and III are both relatively ineffective as contact poisons but are highly effective systemic insecticides. The samples of OMPA available for the present studies were of high purity and consisted almost exclusively of constituent II, prepared with radioactive phosphorus[32]. Sample A[4] had an activity of 1.29×10^6 cts./sec./mM (counts per second per millimole); Sample B[5] had an activity of 3.1×10^5 cts./sec./mM and contained approximately 90 per cent constituent II, while Sample C[5] had an activity of 8.7×10^5 cts./sec./mM and contained 99.72 per cent constituent II and 0.28 per cent constituent I. In certain experiments to be reported, dilutions of the radioactive $OMP^{32}A$ were made with 9 or 10 parts of distilled OMPA of high purity.

Since it was hoped to use the $HCCL_3$/N NaOH partition coefficients of the radioactive fractions as indications of the relative metabolic decomposition of the OMPA into alkali-soluble metabolites, this factor was measured for Sample B, where it was 12 to 1 (92.5 per cent in $HCCl_3$), and for Sample C, where it was 24 to 1 (96 per cent in $HCCl_3$). Hartley *et al.* (1951) found this value for purified OMPA to be 24 to 1. Metabolic breakdown products of OMPA, probably formed by oxidation of a terminal methyl group, as discussed by Hartley (1951), all have much lower partition coefficients in $HCCl_3$/N NaOH.

Leaf samples were prepared by homogenizing in distilled water with a Potter-Elvehjem homogenizer. Aliquots of this homogenate were taken for radiological assay. Partition coefficients for $OMP^{32}A$ and its metabolites were measured by adding 1 ml. of 3N NaOH to 2 ml. of the leaf homogenate to bring the alkalinity to 1N, shaking thoroughly, then adding 3 ml. of chloroform, shaking for one minute, and centrifuging to sepa-

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[4] Obtained through the courtesy of the Monsanto Chemical Company.

[5] Obtained through the courtesy of Pest Control Ltd., England.

rate the immiscible liquids. An aliquot of each layer was then treated with concentrated HNO_3, wet-ashed at 300° C., and counted.

Anticholinesterase activities were measured manometrically (Metcalf & March 1949) by adding 0.1 ml. of a treated-leaf homogenate to 2.6 ml. of a brei of 3 housefly heads per ml. of 0.025 M $NaHCO_3$ buffer, or, in some experiments, 2.6 ml. of bicarbonate containing 8 mg. per 100 ml.[6] of 88×purified human-serum cholinesterase. Three-tenths ml. of 0.1 M acetyl choline bromide was added from the side arm as the substrate, and the volume of CO_2 produced in 30 minutes was compared with a standard containing the same quantity of homogenate from untreated lemon leaves.

The samples for radiological assay were all prepared by wet-ashing with concentrated HNO_3 at 300° C. in a muffle furnace. Ashing was done directly in the cupped, stainless-steel counting planchets. Counts were made with a standard Geiger-Müller end-window tube and were corrected for background and for progressive decay to give values expressed in terms of micrograms of OMPA.[7] Samples showing less than 0.03 count/second greater than background were considered as possessing no activity, since this value represents the standard error of the average background.

The technics for plant growth in water culture and for determination of insect and mite toxicity in Munger cells have been previously described (Metcalf & Carlson 1950). Radioautographs were made of leaves and fruit sections using *No Screen* x-ray film.

DISCUSSION OF RESULTS.—*Uptake of OMPA from Water Culture.*—Lemon seedlings were grown in water-culture solutions containing $OMP^{32}A$, as indicated in tables 1 and 2. At the indicated intervals, 3 leaves were removed from each of three areas (basal, median, and terminal) of the stem of a single seedling. Equal-sized pieces of the tips of the 3 leaves from each area, totaling 0.2 g., were cut off, combined, homogenized, partitioned between $HCCl_3$ and N NaOH, and assayed for radioactivity. The remainders of the leaves were placed in Munger cells, and each was infested with 20 adult female citrus red mites, or, in certain experiments, with 20 adult female greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché).

Table 1.—Distribution of OMPA in leaves of lemon seedlings growing in water culture containing 0.0059 per cent OMPA (1/10 $OMP^{32}A$), and toxicity of leaves to *Paratetranychus citri*.[1]

PLANT NO.	PERIOD PRECEDING ASSAY	POSITION OF LEAVES	OMPA, MICROGRAMS/GRAM OF LEAVES	48-HOUR PER CENT MORTALITY *P. citri*
1	6 hours	Basal	21.3	0
		Median	22.2	5
		Terminal	17.7	5
2	12 hours	Basal	9.0	10
		Median	12.1	20
		Terminal	17.0	40
3	1 day	Basal	4.8	20
		Median	8.5	0
		Terminal	8.8	15
4	2 days	Basal	23.4	60
		Median	35.6	50
		Terminal	41.4	75
5	4 days	Basal	31.2	50
		Median	50.4	75
		Terminal	61.0	100
6	8 days	Basal	88.7	25
		Median	107	90
		Terminal	49.3	65
7	12 days	Basal	68	65
		Median	84	80
		Terminal	96	90
8	16 days	Basal	90	100
		Median	104	95
		Terminal	78.6	95
9	20 days	Basal	61	30
		Median	102	70
		Terminal	147	50
10	24 days	Basal	202	100
		Median	309	90
		Terminal	108	100

[1] Assay values averages of 3 leaves each.

The data in table 1 indicate a progressive increase in the OMPA content of the leaves with time, the amount being appreciable in 6 hours. In this series of plants, comparable measurements were made of basal, median, and terminal leaves to indicate the vertical distribution of OMPA. Distribution of the total OMPA assayed in the selected leaf por-

[6] Obtained through the courtesy of the Cutter Laboratories, Berkeley, California.

[7] Except as noted in specific experiments, values for total OMPA found in the plant tissues by means of radiological assay will be understood to include P^{32}-containing metabolites as well as OMPA itself.

Table 2.—Distribution of OMPA and partition between $HCCl_3$ and N NaOH in leaves of lemon seedlings growing in water culture containing 0.036 per cent OMPA (1/11 $OMP^{32}A$), and toxicity of leaves to *Paratetranychus citri*.[1]

Plant No.	Position of Leaves	Period Preceding Assay	OMPA, Micrograms/Gram of Leaves	Partition Coefficient, $HCCl_3$ / N NaOH	48-Hour Per Cent Mortality *P. citri*
11	Median	6 hours	27.9	7.3	—
	Terminal	1 day	151	7.8	100
	Terminal	2 days	186	5.6	80
	Median	3 days	288	10.7	100
	Median	7 days	605	9.2	100
	Median	11 days	816	6.2	100
12	Terminal	15 days	1,032	9.2	100
	Median	19 days	923	4.4	100
	Basal	23 days	1,050	3.9	100
	Median	27 days	3,860	5.4	—
	Median	31 days	3,890	7.9	85
	Median	35 days	3,780	7.1	100
	Median	46 days	4,590	5.8	100

[1] Assay values averages of 3 leaves each.

tions of the 10 plants in this experiment was as follows:

	OMPA	
Leaf Position	*Micrograms*	*Per Cent*
Basal	599	29
Median	835	41
Terminal	619	30

On this basis, the OMPA passed most strongly to the median leaves. However, the distribution was surprisingly uniform. Substantially the same picture has been obtained using rapidly growing beans (David 1951) in water culture containing about 10 times as much OMPA.

The levels of radioactivity employed in the experiment reported in table 1, using 0.0059 per cent OMPA containing 10 per cent $OMP^{32}A$, were not sufficiently high to permit a desirable degree of accuracy in the measurement of the partition of the OMPA in the leaves between $HCCl_3$ and N NaOH. Therefore, essentially the same experiment was repeated, using larger lemon plants in water culture containing 0.036 per cent OMPA, one eleventh of which was $OMP^{32}A$. The results of this experiment are presented in table 2.

It is evident that lemon seedlings took up OMPA very readily and retained relatively enormous quantities, *i.e.*, of the order of at least 5,000 p.p.m. in the leaves. The values obtained for the $HCCl_3$/N NaOH partition coefficients were somewhat variable, although they seem to indicate a gradual trend toward the decomposition of the OMPA into products soluble in alkali. These products do not appear to be highly insecticidal, as indicated by tests of the inhibitory action of leaf homogenates on fly-brain cholinesterase (ChE), as shown in table 3. In all

Table 3.—Relation of OMPA concentration and of partition between HCC_3 and N/NaOH in leaves of lemon seedlings to inhibitory action of leaf homogenates *in vitro* to fly-brain cholinesterase.[1]

Days Preceding Assay	Total OMPA, Micrograms/Gram of Leaves	Partition Coefficient, $HCCl_3$ / N NaOH	ChE Inhibition, Per Cent
3	288	10.7	7
11	816	6.2	10
15	1,032	9.2	14
31	3,890	7.9	12
47	4,590	5.8	15

[1] Leaf homogenates from plants 11 and 12 (Table 2).

cases a small degree of inhibition was obtained, and it may be that this is responsible for the insecticidal action. However, it will be seen that this inhibition is in no way proportional to the amount of OMPA in the leaf, or to the amount of alkali-soluble metabolites indicated by the partition coefficients. A similar study of leaf homogenates from the plants of the studies reported in table 4, using purified human-serum cholinesterase, gave no cholinesterase inhibition even at 42 days after treatment, when the partition coefficient was as low as 3.

Such information is difficult to interpret. The same procedure of measuring anticholinesterase activities of leaf homogenates of bean plants results in high inhibitory values with equal concentrations of other systemic such as bis-dimethylamino phosphoryl fluoride and 0,0-diethyl 0-2(ethyl mercapto) ethyl thiophosphate (Metcalf & March, unpublished). Therefore, it may be that the inhibitory metabolite is formed in the leaves in small amounts and rapidly destroyed by enzyme action. On the other hand, Hartley (1951) found that an anticholinesterase produced by the oxidation of OMPA with $KMnO_4$ inhibited 50 per cent of the enzyme at 8×10^{-5} M. Assuming that all the OMPA in the leaves of the plants shown in table 2 is converted to inhibitor, a maximum of about 4 mg./gram of tissue, the Warburg flasks used in the inhibition studies would contain

26 micrograms or about 3×10^{-5} M (assuming the same molecular weight as OMPA). It is apparent from the partition coefficients that most of the OMPA is still unmetabolized, so that it appears quite unlikely that the cholinesterase technic, as used, is sensitive enough to demonstrate the inhibitor.

It is interesting to note that no trace of injury to the plants was observed, even in leaves containing more than 6 mg. OMPA per gram.

Translocation of H_3PO_4.—To determine if the ready absorption and translocation of OMPA in lemon seedlings was a unique property of the molecule, a comparable experiment was carried out using P^{32} in the form of H_3PO_4 adjusted with additional phosphoric acid to the same molar concentration (0.00125) in the water-culture solution as of OMPA in the experiment reported in table 2. The uptake of H_3PO_4 by these seedlings is shown in table 4. It is evident that this material is almost as readily absorbed by the roots as OMPA. Maximum amounts of OMPA and H_3PO_4 calculated in terms of micromoles per gram of leaf at various periods after application are shown below for comparison:

	Micromoles/Gram of Leaf	
Period (Days)	*OMPA*	*H_3PO_4*
1	0.53	0.77
3	1.0	1.55
7	2.11	2.43

When comparisons are made on the basis of vertical distribution, however (see Tables 2 and 4), it appears that the OMPA passed more strongly to the upper portion of the plant, whereas the H_3PO_4 was most concentrated in the lower portions. Radioautographs of leaves from these experiments (Fig. 1) indicate concentration of the OMPA in the most rapidly growing portions of the leaf, and a more general distribution of H_3PO_4.

Penetration and Translocation of OMPA Applied to Bark.—Field Studies by Jeppson *et al.* (1952) have shown that applications of OMPA to the trunks of mature citrus trees result in translocation to leaves and fruit in amounts toxic to the citrus red mite. This factor was studied in sour orange seedlings averaging one meter in height, each bearing from 50 to 100 leaves and having a trunk diameter

Table 4.—Distribution of H_3PO_4 in leaves of lemon seedlings growing in water culture containing 0.0217 per cent H_3PO_4.

Period Preceding Assay	Position of Leaves	H_3PO_4, Micrograms/Gram of Leaves
24 hours	Basal	73.9
	Median	70.0
	Terminal	43.3
48 hours	Basal	121
	Median	134
	Terminal	23.2
72 hours	Basal	152
	Median	71.0
	Terminal	31.5
7 days	Basal	154
	Median	238
	Terminal	82
14 days	Basal	151
	Median	106
	Terminal	68
21 days	Basal	169
	Median	308
	Terminal	395
28 days	Basal	220
	Median	212
	Terminal	131

Table 5.—Distribution of OMPA and partition between $HCCl_3$ and N NaOH in leaves of sour orange seedlings treated topically at base of trunk stem with 20 microliters of $OMP^{32}A$, and toxicity of leaves to *Paratetranychus citri*.[1]

Days Preceding Assay	Position of Leaves	OMPA, Micrograms/Gram of Leaves	Partition Coefficient $\frac{HCCl_3}{N\ NaOH}$	48-Hour Per Cent Mortality *P. citri*[2]
1	Basal	17.4	—	37
	Median	29.1	25.2	42
	Terminal	153	21.7	75
2	Basal	30.7	11.0	100
	Median	100	13.8	100
	Terminal	375	—	100
5	Basal	103	10.9	60
	Median	201	13.7	43
	Terminal	546	15.6	63
7	Basal	105	9.5	17
	Median	332	11.6	68
	Terminal	1,085	14.6	75
14	Basal	190	8.4	87
	Median	355	9.9	81
	Terminal	888	11.3	97
21	Basal	236	4.5	97
	Median	322	8.2	88
	Terminal	1,150	8.7	97
28	Basal	283	5.6	95
	Median	371	4.8	100
	Terminal	1,515	7.1	97

[1] Assay values averages of 3 leaves from 3 different plants.
[2] Average of three replicates.

of about 1 cm. Twenty microliters of pure OMP^{32}A (Sample C) were applied to the base of each of three of these plants, about 5 cm. above the soil level. At the intervals indicated in table 5, 1 basal, 1 median, and 1 terminal leaf were removed from each plant. Equal sized pieces of the tips of the leaves from each area were cut off, combined, and 0.2 g. homogenized, partitioned, and assayed for radioactivity as previously described. The amount of OMPA available per plant was about one third of that used in the water-culture experiment of table 2, yet the leaves accumulated OMPA at about the same rate. This indicates that the bark application is surprisingly efficient. In contrast to the experiment recorded in table 1, the OMPA in the present experiment showed a pronounced vertical division in favor of the upper leaves, as revealed in the summation from the data of table 5:

	OMPA	
Leaf Position	*Micrograms*	*Per Cent*
Basal	1,503	12.7
Median	2,628	22.3
Terminal	7,636	65

The partition of the radioactive material between chloroform and N NaOH (Table 5) is particularly interesting, as it definitely indicates an increase in the amount of alkali-soluble material over the duration of the experiment, and appears to show that the alkali-soluble fraction is more concentrated in the lower leaves.

Translocation of OMPA Applied to Leaves.—The rate of translocation of OMPA from one leaf of a citrus plant to other parts of the plant is of practical interest in determining the degree of coverage necessary in spraying with this material. To measure this factor, a single leaf on each of a number of rooted lemon cuttings was treated by topically applying about 1 microliter of OMP^{32}A to the upper surface and then applying 100 microliters of water containing 1 per cent wetting agent, until the entire upper surface of the leaf was evenly wet. The treatments were applied to terminal, median, or basal leaves, or to a leaf on a small lateral branch. After 7-day and 17-day intervals, leaves from various portions of the plants were assayed for total OMPA, as expressed in table 6.

Translocation in these plants was relatively slow but increased appreciably over the test period. At the end of 17 days, from about 0.1 to nearly 1 per cent of the original amount of OMPA applied was found in certain untreated leaves. The translocation appeared to be somewhat stronger in an upward direction, although significant amounts were shown to move downward as much as 16 inches from treated terminal leaves, and also to move upward as much as 19 inches from treated leaves on lateral branches. This seems to indicate that OMPA applied to a single leaf of a lemon seedling eventually spreads throughout the treated plant. Biological assays with citrus red mite adults showed that toxic amounts of OMPA can be translocated in this manner.

It is interesting to note that David (1951), in similar experiments with bean plants, found that nearly 10 per cent of the dosage could be translocated to untreated, actively enlarging leaves within 8 days.

Penetration of OMPA into Lemon Leaves.—The penetration of OMPA into lemon leaves dipped in a solution of 0.1 per cent OMP^{32}A containing 0.01 per cent of the non-ionic emulsifier is shown table 7. The top 5 leaves of a number of

Table 6.—Translocation of OMPA from treated leaves to untreated leaves of lemon cuttings, and toxicity of leaf homogenates to Paratetranychus citri.

	Leaf and Biological Assays After—			
	7 Days		17 Days	
Position of Treated and Untreated Leaves	OMPA, Micrograms /Gram	48-Hour Per Cent Mortality *P. citri*	OMPA, Micrograms /Gram	72-Hour Per Cent Mortality *P. citri*
Terminal leaf (treated)	652	100	757	100
Untreated leaves:				
1 inch below	1.6	15	6.5	50
8 inches below	0	5	4.8	10
16 inches below	0	20	2.0	0
Median leaf (treated)	739	100	3,630	100
Untreated leaves:				
8–10 inches above	0.6	10	5.6	5[1]
1 inch below	1.6	5	3.6	0
8–10 inches below	0.4	15	1.6	15
Basal leaf (treated)	1,335	100	3,220	100
Untreated leaves:				
1 inch above	0.8	10	2.0	5[1]
8–10 inches above	0	10	0.7	5
16 inches above	0	0	1.2	15
Leaf on lateral (treated)	2,960	100	2,200	100
Untreated leaves:				
1 inch below on lateral	0.3	15	—	—
1 inch above on main stem	0.6	5	1.5	5
9 inches above	0	0	0.6	0
18–19 inches above	1.0	15	1.1	10

[1] Mites affected.

Table 7.—Penetration of OMPA into lemon leaves dipped in 0.1 per cent solution containing 0.01 per cent wetting agent.

Hours After Treatment	OMPA			
	Micrograms/Gram		Per Cent	
	In Leaf Surface Residue	In Leaf Homogenate	Penetrated	Recovered
1	152	11.1	6.8	100
6	83.2	18.1	18	62.3
12	67.0	30.7	28.9	59.9
24	55.4	41.8	43.9	59.6
48	43.7	34.1	43.8	47.7
72	17.5	57.2	76.5	47.1
93	18.8	57.7	75.4	47.0
120	31.8	41.0	56.3	44.6

small lemon plants were dipped. At the indicated intervals the treated leaves from a single plant were removed and individually washed in water containing 0.01 per cent wetting agent. An aliquot of the wash water was wet-ashed to determine the surface residue. The leaves were weighed and entirely homogenized in water, and the radiactivity of an aliquot of the homogenate was measured to determine the amount of OMPA which had penetrated.

It will be noted in table 7 that the OMPA penetrated rapidly into the leaf, and that about half had entered within 24 to 48 hours. David (1951), using bean plants in a similar experiment, found a somewhat more rapid penetration, 69 per cent entering the leaves in 24 hours.

In the course of the present experiment, the total amount of radioactive OMPA, in micrograms per gram of leaf weight, in the treated leaves decreased steadily during the experiment, and it was found that large amounts were translocated to untreated leaves, as is shown below:

Hours Between Plant Treatment and Leaf Assay	*Total OMPA in Leaves (Micrograms/Gram)*	
	Treated	*Untreated*
72	74.7 (av. of 5)	1.97 (av. of 3)
120	72.8 (av. of 5)	2.12 (av. of 5)

These data are in good agreement with those of table 6, when it is considered that the leaf area treated initially in this experiment was five times as large as that treated in the preceding experiment.

Distribution of OMPA in Lemon Seedlings Grown in Water Culture.—At the close of the experiments detailed in table 2, aliquots of stem, roots, and leaves were wet-ashed and assayed for total OMPA. The results are given in table 8. The leaves contained by far the largest amounts of OMPA. This is in interesting contrast to the values obtained by David (1951), who found, in similar experiments with bean plants, that the roots contained the largest amounts of OMPA.

Table 8.—Distribution of OMPA in lemon seedling (plant 12, Table 2) after 47 days' growth in water culture containing 0.036 per cent.

Plant Part	OMPA, Micrograms/Gram of Tissue (Av. 3 Samples)	Total Weight of Tissue (Grams)	OMPA	
			Total (Milligrams)[1]	Per Cent
Leaves	7,540	7.81	59.8	69
Stem	997	9.54	9.3	11
Roots	1,160	15.54	18.0	20

[1] These values are approximations only, as they are based on the average of three samples of each tissue.

Concentrations of OPMA Lethal to Test Insects.—From the data in tables 1, 2, and 5, it can be seen that the approximate

Table 9.—Penetration of OMPA into lemon fruits treated with 0.036 per cent aqueous solution containing 0.025 per cent wetting agent.

Interval Between Treatment and Assay	Fruit Maturity	OMPA on Fruit Surface		OMPA in Peel		OMPA in Pulp	
		Micrograms/Sq. Cm.	Per Cent of Total Recovered	Micrograms/Gram	Per Cent of Total Recovered	Micrograms/Gram	Per Cent of Total Recovered
10 minutes	ripe	2.9	100				
	green	2.2	100				
10 days	ripe	0.78	66	0.57	33	0.007	1
	green	0.7	68	0.50	31	0.005	1
18 days	ripe	0.053	15	0.38	76	0.024	9
	green	0.022	—	—	—	0.026	—

Table 10.—Penetration of OMPA into lemon and Valencia orange fruits treated with 0.1 per cent aqueous solution containing 0.04 per cent wetting agent.[1]

Interval Between Treatment and Assay	OMPA on Surface		OMPA in Peel		OMPA in Pulp		Total OMPA Recovered (Micrograms)
	Micrograms/ Sq. Cm.	Per Cent of Total Recovered	Micrograms/ Gram	Per Cent of Total Recovered	Micrograms/ Gram	Per Cent of Total Recovered	
			Lemons				
4 hours	0.99	45	4.4	65	0	0	440
24 hours	0.31	8.2	11.9	91	0.037	1.8	707
48 hours	0.66	23	5.7	76.7	0.014	0.3	474
6 days	0.31	11.3	7.8	87	0.083	1.7	581
8 days	0.32	13.3	7.0	85	0.097	1.7	525
15 days	0.35	16.7	5.8	79.4	0.16	3.9	449
22 days	0.090	3.8	6.8	90.6	0.27	5.6	428
29 days	0.20	8.2	8.2	87.8	0.21	5.0	392
36 days	0.19	6.3	5.5	87	0.25	6.7	490
43 days	0.067	2.7	6.9	88	0.42	9.3	472
50 days	0.11	3	2.8	90	0.18	7	387
57 days	0.066	4	4.31	92	0.20	6	381
			Valencia Oranges				
4 hours	1.60	63	2.5	37	0	0	497
24 hours	0.58	23	7.3	77	0	0	444
48 hours	0.79	29	7.5	70	0.05	1	452
6 days	0.77	39	4.5	60.7	0.008	0.3	414
8 days	0.53	21.5	7.0	76.6	0.078	1.9	509
15 days	0.45	31	3.7	63	0.13	6	302
22 days	0.24	12.8	5.2	81.4	0.18	5.8	366
29 days	0.45	24.8	4.5	68.6	0.17	6.6	355
36 days	0.13	7.5	5.0	84	0.22	8.5	366
43 days	0.11	11.5	2.7	78.4	0.16	10.5	212
50 days	0.34	9.5	4.05	68.1	0.58	21.8	357
57 days	0.17	5	4.46	81	0.32	14.0	345

[1] Assay values averages of 2 fruits each.

concentrations of OMPA lethal to the adult female citrus red mite ranged from 20 to 50 micrograms/gram of citrus leaf for 50 per cent mortality in 48 hours, and from 50 to 100 micrograms/gram of leaf resulted in 100 per cent mortality in 24 hours. Concentrations lethal to the greenhouse thrips are much higher, as would be expected from their feeding habits. These insects were not killed by feeding upon the leaves of the lemon plants, described in table 2, until the 27th to 31st day, when the concentration of OMPA was in the neighborhood of 4,000 micrograms/gram of leaf. The values for the citrus red mite are quite comparable to those which David (1951) found necessary for kill of *Aphis fabae*, viz., 50 micrograms/gram of bean leaf. From the data in tables 1, 2, and 5, it appears that the time required for citrus leaves to become highly toxic to the citrus red mite ranges from 1 to 2 days.

Penetration of OMPA into Citrus Fruits.—The penetration of OMPA into the peel, pulp, and juice of citrus fruits is of especial importance in determining possible toxic residues of this compound. Estimations of this factor, as reported in tables 9 and 10, were made by dipping a number of lemon and Valencia orange fruits on mature trees in the field into aqueous solutions of $OMP^{32}A$ containing wetting agent. Surface residues were estimated by stripping the fruits for one hour with known volumes of water containing 0.1 per cent wetting agent, and then nitrating and wet-ashing aliquots. The fruits were subsequently weighed, measured to compute surface area, and carefully peeled so as not to contaminate the pulp. The peel and pulp were separated and macerated. The data presented in table 9 were obtained by homogenizing the peel and pulp in aliquots of distilled water in a Waring blendor, filtering and extracting the filtrates with chloroform, concentrating to a volume of 1 to 2 ml. and wet-

ashing. The data presented in table 10 were obtained by grinding the peel or pulp of two fruits in a food mill, thoroughly mixing to obtain a representative sample, and nitrating and wet-ashing 1 gram of peel or 2 grams of pulp.

It may be seen from a comparison of the data of tables 7, and 10, that the $OMP^{32}A$ penetrated even more rapidly into the interior of lemon and orange fruits than into lemon leaves. Most of the penetrated $OMP^{32}A$ remained in the peel, but increasing amounts also were found in the pulp, where they eventually reached values of about 0.03 p.p.m. with the 0.036 per cent treatment, and of 0.2 to 0.4 p.p.m. with the 0.1 per cent treatment. The total OMPA recovered from the fruits gradually declined in the course of the experiments. This decline was apparently due to translocation of the OMPA from the fruits to adjacent leaves (Table 11).

Table 11.—Translocation of OMPA from treated citrus fruit to adjacent untreated foliage.

Days Between Treatment and Assay	Fruit[1]	OMPA, Micrograms/Gram in Adjacent Leaves[2]
29	orange	7.1
	lemon	9.8
36	orange	1.6
	lemon	9.0
43	orange	0
	lemon	0

[1] Fruit described in table 10.
[2] Average of 4 leaves.

Metabolism of OMPA in Citrus Fruits.—Ripper *et al.* (1950) have given the rate constant for the hydrolysis of OMPA, at 25° C., as $4.8\times10^{-3}\times[H^+]min^{-1}$. Since this hydrolysis is catalyzed by hydrogen ion, the compound might be expected to be rapidly decomposed by successive breaking of N-P linkages (Hartley 1951) under the acid conditions encountered in citrus fruits. Calculations using this constant indicate that at 25° C., periods required for 50 and 90 per cent hydrolysis are about 312 and 1,040 days, respectively, for the Valencia orange (average pH, 3.5) and about 16 and 53 days, respectively, for the lemon (average pH, 2.2). Since the hydrolysis products partition strongly in favor of N NaOH, measurements were made of the $HCCl_3$/N NaOH partition coefficients of fruits from the experiments reported in table 10. The values obtained are given in table 12. The general trends in peel, pulp, and juice indicate a gradual breakdown of the OMPA over the two months' period, but this does not appear to be as rapid as suggested by the theoretical treatment, probably because OMPA in thr fruit is constantly passing from the peel into the highly acid pulp.

Table 12.—Partition of radioactivity in $OMP^{32}A$-treated lemon and orange fruits of Table 10.

Days Between Treatment and Assay	Partition Coefficients, $\frac{HCCl_3}{N\ NaOH}$					
	Peel		Pulp		Juice	
	Lemon	Orange	Lemon	Orange	Lemon	Orange
22	8	6	—	—	—	—
29	16	—	5	—	—	—
36	24	11	12	—	4	—
43	6	14	7	—	3	—
50	7	11	2	0.5	3	0.7
57	3	8	3	2	2	1

Localization of OMPA in Lemon and Orange Tissues.—Radioautographs showing the distribution of $OMP^{32}A$ in citrus leaves are presented in figure 1A, B, and C. Leaves from plants grown in water cultures containing this compound show a rather uniform dispersal of the material, which appears to be distributed through the veins and to be somewhat concentrated at the periphery of the leaf (Fig. 1A), in contrast to the behavior of $H_3P^{32}O_4$ (Fig. 1D). This peripheral concentration is more evident in the leaf where treatment was made by application to the bark (Fig. 1B). When $OMP^{32}A$ was applied topically at a point on the exterior of the upper leaf surface, as in figure 1C, distribution was largely toward the growing tips, but tended to spread over the entire leaf. The penetration of $OMP^{32}A$ into fruits was more difficult to determine because of the high dilution and low activity of the compound, but it appeared to be largely confined to the peel (compare tables 9 and 10).

SUMMARY AND CONCLUSIONS—P^{32}-tagged octamethyl pyrophosphoramide (OMPA) has been used to study the behavior of this systemic insecticide in lemon and orange plants, and its insecticidal action against the citrus red mite, *Paratetranychus citri* (McG.), and the greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché). More than 500 analyses were made in obtaining the data presented.

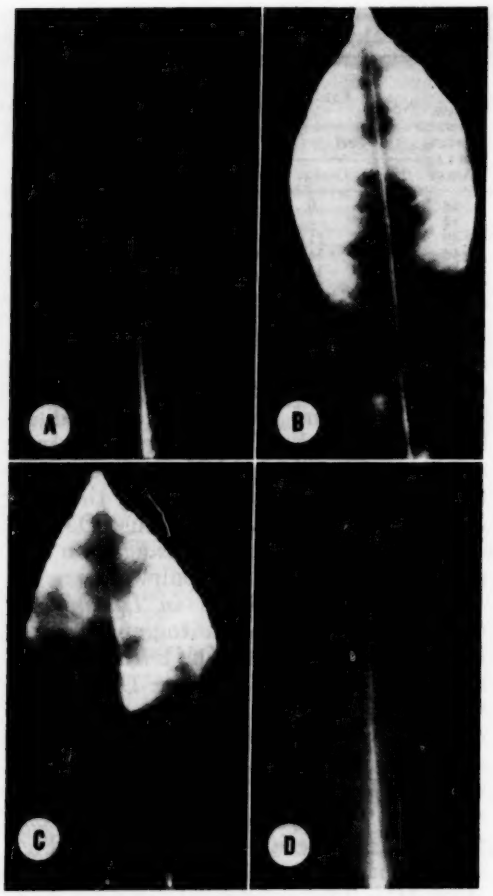

FIG. 1.—Radioautographs showing distribution, in citrus leaves, (A) of $OMP^{32}A$ applied in water culture, (B) of $OMP^{32}A$ applied to bark at base of leaf stem, (C) of $OMP^{32}A$ applied topically to center of upper leaf surface, and (D) of $H_3P^{32}O_4$ applied in water culture.

Studies made by applying the compound in water culture to the roots of lemon seedlings showed that OMPA is readily absorbed and transported to the leaves in rapidly increasing amounts over a 46-day period. Only a small fraction of the OMPA was metabolized in the plant to alkali-soluble, chloroform-insoluble products, although the leaf juices became appreciably toxic to the citrus red mite within 12 to 24 hours. The uptake of the OMPA was not greatly different from that of H_3PO_4 similarly applied.

Leaf juices from plants containing relatively large amounts of OMPA were only slightly effective as inhibitors of fly-brain cholinesterase, and the activity seemed largely independent of the total OMPA concentration. This indicates that any toxic metabolite formed is rapidly decomposed and does not accumulate, as does OMPA, or other metabolities. The distribution of OMPA was surprisingly uniform throughout the various parts of the plant. On a weight basis, the leaves accumulated more OMPA than roots or stems. Translocation was appreciable in all directions from the source of application, but appeared to be greatest in the direction of the most rapidly growing leaves.

When OMPA was applied to the bark at the base of orange seedlings, the material was rapidly absorbed and translocated to the leaves in amounts highly toxic to the citrus red mite, and a pronounced concentration appeared in the terminal leaves. The efficiency of absorption was somewhat greater from this type of application than from water-culture applications.

Applications of OMPA to lemon leaves were rapidly absorbed, and about 50 per cent penetrated to the interior of the leaves within 48 hours. When a single leaf was treated, from 0.1 to 1 per cent of the total dosage passed to other leaves of the plant within 17 days.

Applications of OMPA to lemon and orange fruits were absorbed more quickly into the peel than similar applications into leaves, but penetration into the pulp was not great. The maximum concentrations of OMPA and phosphorus-containing metabolites noted in the juice were 0.03 p.p.m. from the application of 0.036 per cent aqueous solution, after 18 days, and 0.42 p.p.m. from the application of 0.1 per cent solution, after 42 days.

Concentrations of from 20 to 50 micrograms of OMPA per gram of leaf tissue were lethal to the adult female citrus red mite in 48 hours, while a concentration of about 4,000 micrograms per gram of leaf was required to kill the adult female greenhouse thrips.

Radioautographs showing the distribution of $OMP^{32}A$ in orange and lemon leaves were obtained.

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Chromosomal and Cytoplasmic Factors in Transmission of DDT Resistance in the German Cockroach

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Efforts to resolve the problem of insect resistance to insecticides have led to basic research in several fields outside the usual scope of economic entomology. It would appear that the inheritance aspects of this problem have been the least investigated; perhaps this is attributable to the complex mechanism often involved in the inheritance of resistance. In spite of the difficulties inherent in studies of this kind, however, their importance in the final clarification of this problem should not be minimized.

This paper reports the results obtained from reciprocal crosses made between two strains of, *Blatella germanica* Linn., which differed greatly in their ability to survive treatment with DDT.

REVIEW OF LITERATURE.—Among the first suggestions as to how resistance arises in nature were those published by Painter (1930) and Thorpe (1931). Each discussed the presence of groups of individuals within a wild population which appear to differ from the main body of the population. Painter stated that sometimes two or more genetically distinct groups or strains may be present in the same wild population. Elaborating on this idea, Dobzhansky (1941) suggested that varability with respect to insecticide resistance is an example of the genetic variation typically existing in any population. He points out that such variation, which constitutes the raw materials of evolution, develops mainly as a result of gene mutations and chromosomal aberrations. Similarly, Brown (1951) holds that insects are heterozygous for many genes, and that this allows selection to occur for the more resistant individuals when a population is treated with an insecticide. He also mentions that a gene mutation for resistance may occur in the period while chemical control is being applied.

The earliest investigations of the genetic mechanisms involved in the inheritance of resistance are those of Hough (1928, 1934) who made reciprocal crosses between strains of the codling moth, *Carpocapsa pomonella* (Linn.), which differed in their ability to enter apples that had been sprayed with lead arsenate. The progeny from these crosses proved to be intermediate between the two parental strains in their ability to enter sprayed fruit. The back croses produced strains that were intermediate between the F_1 and the parental strain with which it was crossed. Hough reached no conclusions about the genetic mechanism involved, but Brown (1951) interpreted his data as indicating autosomal multiple-gene inheritance.

Dickson (1941) proved that the resist-

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ance to HCN fumigation exhibited by the California red scale insect, *Aonidiella aurantii* (Mask.), is inherited as a simple sex-linked factor. This has been confirmed by Yust *et al.* (1943).

The literature on the inheritance of resistance to DDT in the house fly, *Musca domestica* Linn., is somewhat contradictory. Bruce & Decker (1950) found that a reciprocal cross between resistant and non-resistant strains resulted in the production of progeny whose resistance was intermediate between the two parental strains. They concluded that autosomal multiple-gene inheritance was probably responsible. On the other hand reciprocal crosses made by Harrison (1951) resulted in the production of an F_1 generation which was only slightly more resistant to DDT than the non-resistant parental strain. The F_2 generation from this cross produced a ratio of three nonresistant flies to one resistant fly. This would indicate one-factor, autosomal inheritance with the factor for susceptibility incompletely dominant. The toxicological criterion used by Harrison was different from that of Bruce & Decker, but if her results are correct it would indicate that there are at least two genetic mechanisms involved in producing resistance in the house fly.

In most insect species chromosomal differences are found between the two sexes. (White 1941.) Generally the females have two X chromosomes and the males have an X and a Y. In Lepidoptera and Trichoptera the reverse is true; the females being the heterogametic sex. In most Orthoptera (and some members of other orders) the Y chromosome is absent, so that the females are XX and the males are XO. According to M. J. D. White, this is the situation in the German cockroach.[2]

The physiological bases for the development of resistance are not well understood. Perry & Hoskins (1951) have found, however, that resistant house flies are capable of rapidly degradating DDT to its relatively nontoxic ethylenic derivative, known as DDE, as well as to other non-toxic compounds; and also that they are capable of storing DDT and gradually disposing of it. Perry & Hoskins (1951) have theorized that perhaps DDT-resistant strains of house flies may arise by selection of those possessing an enzyme capable of dehydrohalogenation of DDT.

The DDT-resistant strain of cockroaches used in these experiments was developed in the laboratory by Grayson (1951). He found that at the beginning of the study from two to three times as much DDT was required to kill female raoches as male roaches, and this difference became greater as resistance developed in the strain selected for survival to DDT treatments. No other reference to an insecticide-resistant strain of the German cockroach has been found.

REARING PROCEDURE.—The method employed for rearing the roaches was similar to that described by Heal (1948) with some modifications. An air conditioned laboratory was not available, but the cultures were maintained in a laboratory room in which the temperature was usually between 72 and 78° F., and the relative humidity was raised by constantly exposing water in shallow pans at different points in the room.

Reciprocal crosses between the resistant and non-resistant strains were made twice; first, when the DDT-resistant strain was in the ninth generation of selection for resistance and, secondly, when it was in the eleventh generation. The equivalent generation of the non-resistant strain was used in each case. In addition, the progeny from the eleventh generation crosses were allowed to mate and produce an F_2.

In order to insure virgin females for each cross the sexes were separated within 24 hours after the adult stage was reached. No mating was observed in the first 24 hours following the last molt.

TESTING PROCEDURE.—The order of resistance to DDT of all strains involved in this study was determined by treating known age adults from each strain with different concentrations of DDT. The method of toxicological assay consisted of dipping the roaches in a water suspension of the toxicant at 30°C. The form of DDT used was a wettable powder containing 75 per cent DDT. An electric blender was employed in preparing the water suspensions. It became desirable to change the treatment technique during the course of the study. In the ninth generation crosses the roaches were dipped in the toxicant for 10 seconds and left in the treatment cages for 5 minutes while in the eleventh generation all strains

[2] Personal communication.

Table 1.—Comparison of the toxicity of DDT to several strains of the German cockroach.

	Ninth Generation			Eleventh Generation		
	DDT, gms. per Litre		Times Resistance at LD_{50}	DDT, gms. per Litre		Times Resistance at LD_{50}
	LD_{50}	LD_{90}		LD_{50}	LD_{90}	
Non-resistant males	.034	.066	0	.018	.038	0
B-strain males (F_1)	.082	.230	2.4	.026	.046	1.4
A-strain males (F_1)	.087	.170	2.5	.048	.140	2.7
Resistant males	.195	.670	5.7	.260	1.100	14.8
Non-resistant females	.093	.300	0	.036	.115	0
B-strain females (F_1)	.290	1.200	3.1	.102	.400	2.8
A-strain females (F_1)	.600	9.000	6.4	.195	.700	5.4
Resistant females	6.200	32.000	66.6	12.000	90.600	333.3

were dipped in the toxicant for 15 seconds and left in the treatment cages for 30 minutes before removal to recovery jars. For this reason the quantitative results obtained from the different generations may not be directly comparable, but comparisons within each generation and genetic trends should be valid.

The sexes were treated separately in small screen wire cages. Following treatment the roaches were placed in recovery jars which contained food and water. Observations for mortality were made at the end of 3 and 6 days with the criterion of mortality being lack of locomotion.

The data thus obtained were plotted on logarithmic-probability paper, and regression lines were fitted to the points by the method of least squares (Bliss 1935). In most cases 5 or 6 points were used to establish each line. For each concentration from 50 to 150 insects, in subsamples of 30, were used, and the tests replicated from 2 to 5 times.

Ninety-five per cent fiducial limits were calculated for any lines that were considered close enough that they could be derived from identical populations. In addition, the differences between LD_{50} values of all lines were analyzed to further test whether or not any two lines were coming from identical populations.

Table 2.—Comparison of the toxicity of DDT to the F_2 from the eleventh generation cross.

	Eleventh Generation		
	Conc. of DDT[1]		Times Resistance at LD_{50}
	LD_{50}	LD_{90}	
B-strain males	.060	.200	3.3
A-strain males	.067	.225	3.7
B-strain females	.192	.540	5.3
A-strain females	.220	.725	6.1

[1] Grams per liter.

RESULTS.—The regression lines which resulted from plotting the toxicological data are shown in figures 1 to 3. The LD_{50} and LD_{90} points of these lines, as well as the order of resistance at LD_{50}, are shown in tables 1 and 2. Both the F_1 and F_2 males and females from the cross between DDT-resistant females and non-resistant males are referred to as the A-strain; and F_1 and F_2 males and females from the reciprocal cross, made between non-resistant females and DDT-resistant males, are referred to as the B-strain.

The data show that the progeny from the reciprocal crosses were intermediate, with regard to resistance, between the corresponding parental male and female types (Table 1). The LD_{50} values of the regression lines for all the progeny were significantly different from those of all the parental lines.

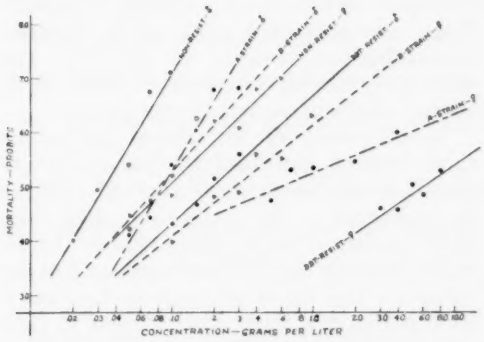

FIG. 1.—Toxicity of DDT at the end of six days to the various strains of the German cockroach involved in the ninth generation reciprocal cross.

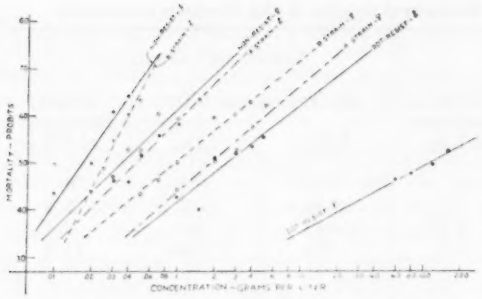

FIG. 2.—Toxicity of DDT at the end of 6 days to the various strains of the German cockroach involved in the eleventh generation reciprocal cross.

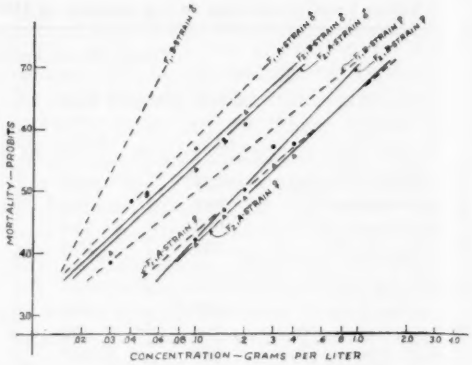

FIG. 3.—Toxicity of DDT at the end of six days to the F_2 progeny arising from the eleventh generation reciprocal cross.

The A-strain males and females were more resistant to DDT at LD_{50} than the corresponding sex in the B-strain (figures 1, 2, and 3). An analysis of the LD_{50} values of the F_1 regression lines showed that these differences are significant in all cases except between A- and B-strain males of the ninth generation cross. In that case the A-strain males were also more resistant at LD_{50} than the B-strain males, but the difference was not significant. Similar results were obtained when the lines were compared by computing the 95 per cent fiducial limits. However, the calculated regression line for the B-strain males fits the actual data so poorly, as judged by a Chi-square test, that even this apparent non-significance may not be valid. Although A-strain females were again more resistant than B-strain females, no significant differences between A and B strains were observed in either the LD_{50} values or the regression lines of the F_2 data.

DISCUSSION.—The data presented in the text indicate that the inheritance mechanism for DDT resistance in the German cockroach is probably complex. Both chromosomal and extra-chromosomal factors seem to be involved, the former probably including both sex-linked and autosomal components.

Involvement of autosomal factors is most clearly indicated by the results of the B-strain cross. Here the only source of resistance is the paternal parent, the DDT-resistant males, from whom the F_1 males receive no X-chromosomes but do receive a full set of autosomes. Inasmuch as the B-strain males were found to possess resistance significantly greater than that of non-resistant males, it would appear that part of the resistance mechanism depends on autosomal genes. The only alternative to this, the assumption of transmission of resistance through the minute cytoplasmic contribution of the sperm, seems rather unlikely. Apparently little or no dominance is involved in the activity of the autosomal factor.

However, autosomal inheritance cannot be the complete explanation since it demands that the results of the reciprocal crosses be identical. It does not explain the significantly greater resistance of the A-strain, F_1 females over the corresponding B-strain females. This difference between the reciprocal crosses was observed in both experiments. It can be explained only by assumption of a cytoplasmic factor for resistance present in the eggs of the resistant females but not in the non-resistant ones. The data indicate that this factor is probably dependent on the nuclear genes for its propagation, since the resistance of the F_2, A-strain females was not significantly greater than that of the B-strain, F_2 females. Apparently the A-strain, F_1 females were not capable of transmitting the cytoplasmic factor. This would be easily understood if the ability to produce the cytoplasmic factor depended on a recessive gene. Neither the A-strain, F_1 females nor the B-strain, F_1 females would be homozygous for this gene and, therefore, they could not produce the cytoplasmic factor. In Paramecium the extensive work of Sonneborn (1947, 1951) has shown that the cytoplasmic factor Kappa cannot be propagated long in the absence of a specific gene. Similarly many cytoplasmic male-sterility factors in plants are known to be under genetic control (Caspari 1948; Srb & Owen 1952).

The cause of the greater resistance exhibited by females over males in all strains is not clear. Its occurrence even in non-resistant strains suggests a fundamental physiological difference between male and female tissues of the German cockroach in their ability to survive treatment with DDT. The accentuation of this difference during selection for resistance may be attributable to sex-linked genes for resistance. These would increase in number faster in females than in males. While the explanation of the data presented in this paper does not specifically demand its presence, the assumption of this additional chromosomal component in resistance is not unreasonable. The possibility exists also that the cytoplasmic factor cited above is more active in the female than in the male. Such differential activity in different genic and extragenic environments is a particularly common attribute of cytoplasmic inheritance (Caspari 1948).

SUMMARY.—Reciprocal crosses were made between DDT-resistant and non-resistant strains of the German cockroach *Blatella germanica* Linn. The crosses were made twice; first, when the DDT-resistant strain was in the ninth generation of selection for resistance and, secondly, when it was in the eleventh generation. In addition, the progeny of the eleventh generation crosses were allowed to mate and produce an F_2 generation.

The order of resistance of the various strains of roaches involved was determined by dipping adults from each strain in aqueous suspensions of DDT at different concentrations. The data thus obtained are presented in the form of regression lines with appropriate statistical analyses. The LD_{50} and LD_{90} values, as well as times resistance at LD_{50}, are presented.

The data show that the inheritance mechanism for DDT resistance in the German cockroach is complex. Both chromosomal and extra-chromosomal factors seem to be involved, the former probably including both sex-linked and autosomal components. The extra-chromosomal factor is probably dependent upon nuclear genes for its propagation. The differential ability of males and females to survive treatment with DDT suggests a fundamental physiological difference between the sexes. Accentuation of this difference as selection for resistance progressed may be due to sex-linked genes.

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Soil Insecticide Studies in Oregon[1]

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Considerable progress has been made in recent years in the chemical control of injurious soil arthropods. This has been due principally to the development of new soil fumigants and machinery for their application. Economical control with fumigants has been demonstrated on land used for growing of high priced crops. Unfortunately the correct timing of applications and the soil conditioning necessary for successful use of soil fumigants cannot always be made to fit into established horticultural practices. Fumigants have an added disadvantage in the short duration of their effectiveness in the soil.

More recently, the development of DDT and newer chlorinated hydrocarbon insecticides has resulted in a change in the research pattern. These new materials have definite residual properties and the timing of their application is of minor importance.

Studies at the Oregon Agricultural Experiment Station on the effects of adding residual insecticides to the soil have been in progress since 1947. Some of the earlier work on the effects of BHC in the soil on certain crops and weeds (Morrison, *et al.* 1948) and on the cabbage maggot (Crowell, *et al.* 1948) has already been published. These preliminary trials were of sufficient promise to stimulate additional work with various toxicants as well as investigations on depth and degree of mixing, concentrations, off-flavor in food produce and other factors involved in the use of soil insecticides.

Soil Mixing and Plot Size Studies, 1948–49.—Since the early trials with benzene hexachloride indicated that the degree of mixing of the insecticide with the soil affected the degree of cabbage maggot control, experiments were conducted to study methods of tillage in relation to insecticidal placement. Facilities were not available for chemical soil analyses, so a technique was developed using iron filings and turnings.

The iron particles were obtained from a machine shop and passed through a quarter inch screen. They were then scattered over the soil at the rate of about 10 pounds per square rod. After the plots were tilled, soil cores were taken and divided into sections representing different depths. The iron particles were removed from the air-dried soil samples by means of a small, permanent magnet. A cellulose actate shield was used to keep the particles from coming into direct contact with the magnet. The recovered iron was washed with water, dried with acetone and weighed. The weight of the particles from each depth sample was expressed in terms of per cent of the total weight of recovery in the 6 or 8 inch soil core.

Rotary tillage and double discing were studied in this manner in several soil types. Soil samples were also taken to determine how far the equipment would drag the iron particles from the treated plot. The results of these tests are presented in tables 1, 2 and 3.

It can be seen from these tables that seed bed preparation, method of tillage and the soil type greatly influenced the thoroughness of mixture. It is unfortunate that the iron particles data could not be correlated with chemical analyses of an insecticidal application, since the greater density of the filings and turnings may have influenced their placement in the the soil. Studies of this type are in progress at the present time.

In table 3 it may be seen that the tillage equipment dragged a substantial amount of the iron particles several feet beyond the plot boundaries. That dragging does take place with insecticides, as well as with the iron, was substantiated by biological observations on serveral insecticide-treated plots. In one instance, weed control was observed four to five feet beyong the limts of a heavy BHC application. In another case, the influence of cross tillage from treated to untreated plots was measured in terms of tuber flea beetle injury on potatoes.

The movement of soil insecticides by tillage creates a troublesome problem in field plot teachnique. To overcome this difficulty, small replicated and randomized plots have been replaced by

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Table 1.—Relationship between soil type and tillage method to degree and depth of mixture of iron particles in soil.

Soil Type	Tillage Method	Per Cent Iron Particles Found in Top 2⅔ in.	Middle 2⅔ in.	Bottom 2⅔ in.
Fine sandy loam	Rotary tilled once	45	44	11
Fine sandy loam	Double disced twice	46	42	12
Loam	Rotary tilled once	28	50	22
Loam	Double disced four times	62	33	5
Clay	Rotary tilled once over rotary tilled soil	36	28	36
Clay	Rotary tilled once over plowed soil	54	34	12
Clay	Disced six times over plowed soil	50	40	10

Table 2.—Relationship of number of times rotary tilled to degree and depth of mixture of iron particles in soil.

Soil Type	Times Rotary Tilled	Per Cent Iron Particles in 1st and 2nd in.	3rd and 4th in.	5th and 6th in.	7th and 8th in.
Clay	Once over plowed soil	48	29	19	4
Clay	Twice over plowed soil	22	23	23	32

Table 3.—Relationship between tillage method and dragging of iron particles from point of application.

Soil Type	Tillage Method	Distance from Application Point	Per Cent of Particles Dragged from Application Point
Loam	Rotary tilled once	5 feet	1.6
		10 feet	1.3
		20 feet	0.9
		Total	3.8
Loam	Disced four times	5 feet	7.1
		10 feet	12.4
		20 feet	0.4
		Total	19.9

long, narrow plots. These plots parallel the direction of tillage and cultivation and their size is governed largely by the available tillage equipment and the type of crop to be grown. In general this system of field plot design increases the size of plots and reduces the number of replications possible. The skewed population distribution exhibited by some soil arthropods further complicates field plot technique.

INSECTICIDE PLACEMENT TESTS, 1949–50.—Field trials in 1948 with cabbage maggots on turnips gave some perplexing results. Eighteen pounds of gamma BHC per 2 inch acre raked into the soil gave control which was inferior to 10 pounds of gamma BHC tilled into the soil to a depth of 6 inches. This led to the desire to explore the problem of depth of mixture in more detail.

In 1949, a series of replicated experiments were set up using tin cans (No. 10 size) for the individual plots. BHC wettable powder was mixed with sandy loam in a concrete mixer.

The treated soil was then layered in the cans at various depths and thicknesses. The series were arranged so that each inch layer contained BHC at the rate of 1.67 pounds gamma per acre. One, two, three and six inch layers were used. In this way all the cans in the first series containing single inch layers had a total amount of toxicant equivalent to a rate of only 1.67 pounds per acre. The series with two and three inches of treated soil contained toxicant equivalent to 3.33 and 5 pounds per acre, respectively. The location of the treated soil was varied according to depth and made up to a total of six inches with untreated soil in each case. The last series, containing six inches of treated soil (all of the soil treated), had a total toxicant content equivalent to 10 pounds per acre.

The cans were sunk into the ground and planted to turnips. The turnips were scored for maggot injury at the end of the season. The arrangement of the treated soil layers, together with the results of the maggot scoring are presented in Figure 1.

These tests showed that good cabbage maggot control could be obtained with 10 pounds of gamma BHC per 6 inch acre. Direct comparisons with the different series is difficult because of different dosages. It appeared, however, that insecticidal placement modified the expected dosage mortality curve, but was not conclusive.

A similar experiment was carried on in 1950 with a rate of 10 pounds of gamma BHC per acre inch used as the base. In this way, each inch of treated soil contained 10 pounds of the toxicant. The series containing two, three and six inches of treated soil totaled, respectively, 20, 30 and 60 pounds of gamma BHC. The arrangment of these treated soil layers, together with the results of the maggot scoring, are presented in Figure 2.

The two seasons' results indicated that insecticidal placement was important in determining the degree of control of

Soil Profile showing location of treated layers (lbs./acre in.)	Depth in inches											
	1	1.67						1.67			1.67		1.67
	2		1.67					1.67			1.67		1.67
	3			1.67					1.67		1.67		1.67
	4				1.67				1.67			1.67	1.67
	5					1.67				1.67		1.67	1.67
	6						1.67			1.67		1.67	1.67
Total gamma BHC pounds/acre		1.67	1.67	1.67	1.67	1.67	1.67	3.33	3.33	3.33	5.00	5.00	10.00
% Maggot Control		13	0	14	6	0	0	56	0	0	65	58	100

FIG. 1.—The 1949 insecticide placement tests. A comparison of cabbage maggot control on turnips grown in #10 cans with treated soil layered at different depths and thicknesses. Each treated inch of soil contains BHC at the rate of 1.67 pounds gamma per acre. The dosages range from 1.67 pounds gamma per acre (one treated inch to 10 pounds per acre (6 treated inches).

cabbage maggots. When the insecticide was not mixed to the 6 inch depth, even three times the minimum effective dosage did not result in complete control.

The #10 tin cans used in these trials were found to have serious disadvantages. They were too small for adequate growth and did not maintain sufficient moisture without frequent irrigations. A series of trials in 1950 showed that sheet aluminum collars (8 inches deep and 1 foot in diameter) were much more satisfactory. They were only partially crimped so that they could be removed from the soil at the end of the season, cleaned and flattened for storage Having no bottom, they required no more irrigation than when the crops were grown in the open soil. It has been found, however, that the collars will not be good for more than two or three seasons because of the electrolytic pitting of the aluminum in contact with the moist soil.

These collars have also been used for the purpose of screening soil insecticides. Toxicants at the desired concentrations are mixed with the soil with a concrete mixer. Cabbage maggots and tuber flea beetles have been sufficiently abundant each season as test insects. Materials screened out as having little value against these insects are methoxychlor, TDE, CS 708, and piperonyl butoxide-pyrethrum combinations.

SOIL INSECTICIDE LONGEVITY TESTS AT CORVALLIS.—In order to study the longevity in the soil of some of the newer insecticides, a series of eleven field plots was established in the spring of 1949. Three of these plots (20′×50′ each) were used as untreated checks, and each of the eight remaining was treated with a different material. All of the insecticides were applied at the rate of 10 pounds of the active ingredient per 6 inch acre by means of a small (3 foot) fertilizer applicator.

Soil Profile showing location of treated layers (lbs./acre in.)	Depth in inches											
	1	10						10			10		10
	2		10					10			10		10
	3			10					10		10		10
	4				10				10			10	10
	5					10				10		10	10
	6						10			10		10	10
Total gamma BHC pounds/acre		10	10	10	10	10	10	20	20	20	30	30	60
% Maggot control		38	73	87	78	33	0	87	58	5	80	34	100

FIG. 2.—The 1950 insecticide placement test. A comparison of cabbage maggot control on turnips grown in #10 cans with treated soil layered at different depths and thicknesses. Each treated inch of soil contains BHC at the rate of 10 pounds gamma per acre. The dosages range from 10 pounds gamma per acre (one treated inch) to 60 pounds per acre (six treated inches).

Table 4.—Residual soil treatments for tuber flea beetle control Corvallis longevity soil plots. 1949–51.

		FLEA BEETLE INJURIES PER 10,000 SQ. CM.‡					
		1949		1950		1951	
TREATMENT*	RATE†	Mean	% Control	Mean	% Control	Mean	% Control
DDT	10	1180	77	1365	77	2424	12
EPN	10	278	95	5055	8	2716	2
Parathion	10	50	99	2782	52	4517	0
Toxaphene	10	25	99.5	99	98.3	241	91
Chlordane	10	5	99.9	8	99.8	37	99
Aldrin	10	4	99.9	8	99.8	20	99
Dieldrin	10	2	99.9	4	99.9	27	99
BHC (gamma)	10	4	99.9	4	99.9	18	99
Heptachlor	10	—	—	—	—	12	99
Check 1	—	5959	—	7821	—	1835	—
Check 2	—	5293	—	4830	—	4048	—
Check 3	—	4172	—	4795	—	2395	—
Mean check		5141	0	5851	0	2759	0

* Heptachlor applied 1951. All other materials applied 1949.
† Pounds of active ingredients per 6 inch acre.
‡ Statistical studies of tuber flea bettle injuries on potatoes (injuries per tuber, injuries per pound, injuries per square centimeter) have shown that less variance exists within samples of potatoes when injuries are expressed in terms of unit area.
On the assumption that potatoes are spheroid in shape, regression lines between weight-volume, volume-area (Turrell) and weight-area were calculated. Area of a potato is determined from the formula $A = Wt.\ (0.5227) + 45.45$, where area is expressed in square centimeters and weight in grams.
Injuries per 10,000 square centimeters is an arbitrary figure which was adapted for convenience in the use of whole numbers. Twenty-five tubers, selected at random have been adequate for scoring flea bettle injuries.

Wettable powders, thoroughly mixed with fine sand as an extender, were used in all cases. The materials included in this study were DDT, toxaphene, chlordane, BHC, aldrin, dieldrin, parathion and EPN. A twelfth, heptachlor, was added to the series in 1951. Each plot has been rotary tilled individually in order to preserve plot identity. Crops such as potatoes, corn, beans, carrots and either turnips or radishes have been planted each year for observations on insect control, plant injury and flavor quality.

CONTROL OF LARVAL FORMS OF INSECT PESTS.—Insects common to this river-bottom, sandy loam soil are wireworms (*Limonius canus* Lec. and *L. californicus* Mann.), cabbage maggots (*Hylemya brassicae* (Bouché) and *H. fugax* (Mg.)), the seed corn maggot

Table 5.—Residual soil treatments for wireworm control. Corvallis longevity soil plots. 1949–51.

		WIREWORM INJURIES PER 100 POTATO TUBERS					
		1949		1950		1951	
TREATMENT*	RATE†	Mean	% Control	Mean	% Control	Mean	% Control
DDT	10	108	81	32	87	18	95
EPN	10	0	100	8	97	132	65
Parathion	10	4	99	212	16	100	73
Toxaphene	10	28	95	16	94	26	93
Chlordane	10	16	97	12	95	0	100
Aldrin	10	4	99	0	100	0	100
Dieldrin	10	0	100	0	100	0	100
BHC (gamma)	10	0	100	0	100	3	99
Heptachlor	10	—	—	—	—	0	100
Check 1	—	508	—	304	—	520	—
Check 2	—	818	—	280	—	332	—
Check 3	—	372	—	172	—	228	—
Mean check		566	0	252	0	377	0

* Heptachlor applied 1951. All other materials applied 1949.
† Pounds of active ingredients per 6 inch acre.

Table 6.—Residual soil treatments for cabbage maggot control. Corvallis longevity soil plots. 1949–51.

Treatment*	Rate†	Per Cent Marketable Turnips			Rating‡
		1949	1950	1951	1951
DDT	10	0	3	2	196
EPN	10	3	3	0	200
Parathion	10	2	1	0	200
Toxaphene	10	1	0	0	200
Chlordane	10	23	0	2	197
Aldrin	10	92	58	52	118
Dieldrin	10	67	27	94	45
BHC (gamma)	10	95	58	52	124
Heptachlor	10	—	—	94	37
Check 1	—	0	8	0	200
Check 2	—	0	0	0	200
Check 3	—	0	1	2	198
Mean check	—	0	3	1	199

* Heptachlor applied 1951. All other materials applied 1949.
† Pounds of active ingredient per 6 inch acre.
‡ The rate of kill of cabbage maggots seemingly varies with the insecticide. Maggot blemishes, similar to codling moth larval stings on apples, may occur. A system of scoring has been unofficially adopted by cabbage maggot investigators of the Pacific Northwest Vegetable Insect Conference in which the value of zero (0) is assigned to clean turnips, one (1) to turnips with one blemish (sting), two (2) to turnips with two blemishes and four (4) to turnips considered unmarketable (maggoty or with more than two blemishes). Rating is based on values accumulated from 50 turnips and the maximum score is 200.

(*Hylemya cilicrura* (Rond.)), larvae of the Western spotted cucumber beetle (*Diabrotica undecimpunctata* Mann.), and the tuber flea beetle (*Epitrix tuberis* Gent.). These insects, when present, are fairly well distributed over the experimental area of about $\frac{1}{4}$ acre.

It is recognized that these unreplicated field plots are not in accord with recognized principles of field design and that biometric analyses of data received from them are not applicable. The complicating factors arising from recognized field plot techniques have already been discussed. The standard error of insect control within plots has been measured from a series of randomized samples. These have been used to compare differences between treatments each season. Insect control with many of these treatments has been so outstanding that statistical evaluation of results has not been of major importance.

The results obtained over three seasons from insect control observations made in these longevity plots have been summarized in Tables 4, 5 and 6.

EFFECT OF SOIL TREATMENTS ON EMERGENCE OF ADULT INSECTS.—A start was made in 1950 to study the effect of residual soil treatments on the emergence of adult insects which spend at least the pupal stage in the soil. Funnel-shaped aluminum emergence cages were constructed which would cover 4.5 square feet of ground surface. These were placed over the old turnip rows in the Corvallis longevity soil plots on April 6, 1950, and all insects emerging over a 46-day period were collected at two-day intervals and mounted for determination. Only the data on *Hylemya* species have been compiled at the time of writing. These results have been summarized in Table 7, together with the 1949 results on maggot control. The total numbers of all adult insects collected in the emergence traps is also listed. These consist of over 100 species, 50 families and 3 orders.

This preliminary study on adult insect emergence from insecticide-treated soil has already given some interesting indications. Chlordane allowed maggots to enter turnips to the extent of making 77% of them unmarketable, but almost no adult flies emerged. Aldrin, dieldrin and BHC apparently controlled the *Hylemya* maggots so well as to exclude much possibility of any adult emergence. Toxaphene showed no control of *Hylemya* larvae, but allowed so many adults to emerge as to suggest some action on the natural parasites and predators. A study of the other insects collected from these plots may throw additional light on this subject.

Unfortunately the emergence cages in this study were not replicated and statistical significance cannot be credited to the data. In this undertaking only one crop (turnips) was used and over 9000 specimens were collected. Adequate replication would probably require four to five emergence cages per crop in each plot and the number of specimens collected would be astronomical. In order to obtain a complete picture of the effects of soil treatments on insect fauna, however, studies of this kind should be undertaken according to crop, soil type and region. These studies would shed valuable insight on some of our little known insects. The problem is not without its practical aspects. There are indications that parasites, predators, scavangers and saprophytic insects have been controlled by soil insecticides. A continuous control of these forms of insects may adversely affect agriculture.

FIELD TRIALS IN PEAT SOIL, 1949–50.—In 1949 a series of field plots were established in peat soil at Lake Labish

Table 7.—Summary of *Hylemya* adult emergence in 1950 from 1949 planted turnips in the Corvallis longevity soil plots.

TREATMENT	RATE (lbs./6 in. A.)	PER CENT MAGGOTY TURNIPS IN 1949	*Hylemya* ADULT EMERGENCE* April 6 to May 22, 1950			TOTAL OF ALL INSECTS COLLECTED
			H. brassicae	*H. fugax*	*H. cilicrura*	
DDT	10	100	44	4	4	645
EPN	10	97	85	6	0	795
Parathion	10	98	79	5	6	1538
Toxaphene	10	99	61	7	21	1367
Chlordane	10	77	1	0	1	235
Aldrin	10	8	0	0	0	218
Dieldrin	10	33	0	1	0	159
BHC (gamma)	10	4	0	2	0	92
Check 1	—	100	50	1	0	1669
Check 2	—	100	19	0	0	231
Check 3	—	100	45	2	0	2359

* Determinations by C. W. Sabrosky.

for the study of concentrations, methods of application and effective longevity of two insecticides against the carrot rust fly *Psila rosae* (F.). In these trials toxaphene at 10 and 20 pounds and chlordane at 4 and 6 pounds of actual toxicant per 6 inch acre were used. The plots (16 feet by 100 feet) were replicated three times and extended the entire width of the field in order to facilitate tillage and cultivation without loss of identity. Wettable powders were applied dry (with a fertilizer applicator) and as sprays, and then immediately rotray tilled into the soil to a depth of at least six inches.

Because of the extreme lateness of the fall brood of rust flies, scoring of the carrots for injury was postponed each year until the following March. In this way the carrots, planted in June, were exposed to two broods of the pest during both years of the trials.

A summary of the rust fly control results is presented in Table 8.

Statistical evaluation of the data obtained from these tests showed no significant differences due to treatments or to methods of application in either season. The differences obtained between treatments and checks were found to be highly significant and the control of rust fly injury obtained was commercially practical.

Table 8.—Results of carrot rust fly soil treatments in peat soil, Lake Labish, Oregon, 1949–50.

TREATMENT	RATE*	PER CENT WORMY CARROTS	
		1949	1950
Toxaphene	10	4.0	3.2
Toxaphene	20	0.3	2.4
Chlordane	4	1.8	1.5
Chlordane	6	0.5	1.7
Check (untreated)		65.5	41.1

* Pounds of active ingredient per 6 inch acre.
Mean value dust application—1.65 per cent injured carrots.
Mean value spray application—0.54 per cent injured carrots.

The aluminum funnel cages were used in the spring of 1950 to check on fly emergence from the soil in these plots. Four cages in treated plots produced a total of one fly during a 35-day period, while six cages placed over carrots in the check plots captured 250 rust fly adults.

In 1951 the experimental area was planted to mint by the owner and no further information on longevity of the materials in the soil was possible. As can be seen from Table 8 above, however, the two materials were still effectively controlling the carrot rust fly two years after application.

COOPERATIVE STUDIES.—Early in the study of residual soil insecticides, it became evident that certain phases of research were beyond the scope of entomology. It was observed that some insecticides when applied to the soil could have either a toxic or stimulating effect on certain plants. Off-flavor was readily detected in some vegetables when BHC was applied to the soil. It is conceivable, however, that other insecticides which promote a rapid rate of growth might cause a difference in time of maturing. This could also contribute to flavor difference.

Several departments of the Oregon Agriculture Experiment Station are now actively engaged in various phases of the

study of residual soil insecticides. The Food Technology Department has been studying the flavor and quality of commodities grown in insecticide-treated soil. The Agricultural Chemistry department is engaged in chemical and bioassay studies of treated soil and of produce grown in the soil. The Bacteriology Department has been studying the effect of insecticides on soil microorganisms. The Agricultural Engineering Department is working on ways and means of applying insecticides to and into the soil. Information on these projects will be published separately. Additional work by agronomists, horticulturists and plant physiologists is needed.

LARGE SCALE FIELD TRIALS, 1951–52.—Information collected on residual soil insecticides during the period of 1947–50 was obtained from small plots. It became necessary to obtain additional information on the most promising of these materials when applied to different soil types and areas of Oregon with conventional equipment.

Nineteen different field experiments (58 plots) were set up in 1951 using aldrin and dieldrin at various rates per 6 inch acre. Plots varied in size from one tenth acre to 8 acres. In 1952 fourteen additional field experiments were established (60 plots) with aldrin, dieldrin, chlordane, and heptachlor applied at various rates per 6 inch acre.

Materials were applied with either a Bean power sprayer equipped with an 11-foot boom, or mixed with fertilizers and applied with conventional fertilizer applicators. When materials were applied as sprays, either wettable powders or emulsion concentrate formulations were used.

Immediately after application, materials were worked into the soil to approximately 6 inches with either double discs, rotary tillers or rotary hoes. Commodities which have been grown in these plots include corn (field and sweet), squash, mint, tomatoes, beans (bush and pole), strawberries, potatoes, onions, carrots, beets, cole crops, and lily bulbs.

Soil samples were taken from all of the 1951 plots according to the method of Koblitsky and Chisholm (1949). These were submitted to the Departments of Bacteriology and Agricultural Chemistry (Terriere 1952) for special studies.

Commodities such as sweet corn, potatoes, squash, tomatoes, beans and carrots were submitted to the Department of Food Technology for studies on taste and quality. It has been learned that more reliable results can be obtained in flavor and quality evaluations of commodities when experienced individuals carry on the culture, harvesting and processing. Produce from the 1951 plots met these requirements. Results on taste and quality tests will be published separately. Residue studies on commodities grown in these treated plots were made by the Department of Agricultural Chemistry (Terriere 1952).

RESULTS OF THE 1951–52 FIELD TRIALS.—Complete results of some of the 1951–52 field trials may not be obtained until 1954 or later. In general the results on pest control from these experiments can be summarized as follows:

1. Symphylids, *Scutigerella immaculata* Newp., have been effectively reduced with either aldrin or dieldrin at 10 pounds per 6 inch acre in most of the plots. Thorough mixture of the insecticide with the soil appears to be necessary. The degree of control has been dependent on the severity of infestation. Rate of control has been slow and symphylid damage to crops has occurred during the first season. In general control has improved during the second season after treatment.

2. At Madras, Oregon, dry land wireworms (species undetermined) were effectively controlled with aldrin. A rate of 2 pounds per 6 inch acre was as effective as the 4 and 6 pound dosages for protection of potatoes.

At Hermiston, Oregon, aldrin dosages at 5 and 10 pounds per 6 inch acre were equally effective against *Limonius canus* Lec. and *L. californicus* Mann. Wireworm control was measured by the degree of injury on potato tubers. At Dayton, Oregon, a shallow application of aldrin at 10# per 2 inch per acre failed to give adequate control. Chemical analysis showed aldrin in the soil at a concentration of 5.1 p.p.m. This further illustrates the importance of thorough and deep mixing of insecticide in the soil.

3. The tuber flea beetle, *Epitrix tuberis* Gent., was well controlled with aldrin at Redmond, Oregon. Two pounds per 6 inch acre was as effective as 4 and 6 pound dosages. At Corvallis, Oregon, a 1.5 pound per 6 inch acre dosage of aldrin

was equal to a 3 and 4.5 pound dosage. Control was again estimated from the degree of injury on potato tubers.

4. Aldrin at the rate of 2, 4 and 6 pounds per 3 inch acre gave commercial control of the onion maggot, *Hylemya antiqua* (Meig.) in peat soil at Lake Labish, Oregon. No differences could be measured between treatments, and the control obtained was equal in value to the standard chlordane treatment of 2 pounds per acre applied as a drench at the time of seeding.

5. Aldrin at 1, 3 and 5 pounds per 6 inch acre successfully controlled a light infestation of the carrot rust fly, *Psila rosae* (F.), in sandy loam at Jefferson, Oregon. No differences between treatments could be measured.

6. Light infestations of the Western spotted cucumber beetle, *Diabrotica 11-punctata* Mann., at Corvallis, Oregon, prevented the collection of conclusive data on control.

7. At Gresham, Oregon, deep plowing of treated plots, which were established for control of cabbage maggots, *Hylemya brassicae* (Bouché) and *H. fugax* (Mg.), seemingly buried the insecticide too deep for effective control.

8. At Hermiston, Oregon, 5 pounds of aldrin per 6 inch acre gave strong indications of controlling the seed corn maggot, *Hylemya cilicrura* (Rond.), in lima beans the second year after application.

DISCUSSION AND CONCLUSIONS.—In the control of soil arthropods by residual soil insecticides, it is apparent that dosage mortality and time mortality curves will vary according to species and material. The effective range of broadcast applications for the more promising soil insecticides is likely to vary from 0.25 pound to 10 pounds per 6 inch acre. It if is assumed that a 6 inch acre of soil weighs 2,000,000 pounds, this represents 0.125 and 5 p.p.m. respectively.

Chisholm and Koblitsky (1952) have ably discussed the limitations of weight-volume and weight-weight bases for expressing dosages of soil insecticides. However, considerable confusion could be avoided in literature if investigators would accept 2,000,000 pounds as an arbitrary standard for a 6 inch acre and report dosages both in terms of weight-volume and weight-weight.

Toxicants applied as seed treatments, side dressings, band treatments and drenches may also be considered as soil insecticides since they are used to treat a limited volume of soil. Seed treatments have been used at the rate of two ounces of toxicant per 100 pounds of seed. The degree of seed protection by chemicals, however, varies with the number of seeds per pound, rate of planting and width of rows. If it is assumed that seed treatments affect a volume of soil 1 inch in diameter, then the concentration of the toxicant in the treated portion could vary from 0.5 p.p.m. in the case of carrots to 13 p.p.m. for corn. In like manner, side dressings or drenches may be assumed to protect a volume of soil about $3\frac{1}{2}$ inches in diameter. If applied at the rate of 2 pounds of toxicant per acre, the concentration in the core could vary from $7\frac{1}{2}$ p.p.m. to 30 p.p.m. for 12 inch and 48 inch rows, respectively.

The longevity of soil insecticides is one of the most difficult problems now associated with soil pest control. Dosages of 10 pounds per 6 inch acre have remained biologically effective in Oregon for a three year period. Other investigators have reported a longer period of crop protection.

Chemical and biological studies have shown that soil insecticides slowly decline in concentration. Fleming, *et al.* (1951) in studying insecticide persistence in turf-treated soil, showed the rate of decline of chlordane to be considerably greater than that of DDT. Preliminary investigations in Oregon (Terriere 1952) are somewhat at variance with these results. Fleming, however, worked with materials in the 3 inch acre and Terriere was using 6 inch acre applications. The problem is complex because many factors associated with insecticide breakdown are unknown. It is reasonably certain that leaching is not very important with the chlorinated hydrocarbon materials. Smith (1948) demonstrated the stability of DDT in both acid and alkaline soils. Cullinan (1949) was able to show that certain soil microorganisms contributed to insecticide breakdown. Cultivation and tillage practices are probably important in reducing the concentration of the toxicant, since each stirring of the soil brings new material to the surface for volatilization or chemical breakdown. The problem of longevity has its practical aspects. It

will soon be necessary to advise growers as to how much additional material should be added to their soil each season in order to maintain the required protection of their crops. Excessive and too frequent use of soil insecticides can eventually lead to serious diffiulties.

SUMMARY.—Residual soil insecticides have been studied in Oregon during the period 1947–1951. Soil arthropods under investigations in this work include symphylids, wireworms, tuber flea beetles, cabbage maggots, seed corn maggots, onion maggots, carrot rust flies and western spotted cucumber beetles.

The techniques used for screening new materials and for testing insecticidal placement and the degree of mixture with the soil are described.

DDT, toxaphene, and chlordane have been found to have residual action, but are specific in their effectiveness. EPN and parathion are also specific and have little residual action beyond a year. BHC is an excellent all-purpose soil insecticide but imparts objectionable off-flavor to some food crops. Aldrin and dieldrin seem to meet the requirements for all-purpose soil insecticides and remain effective for several years. Limited tests indicate that heptachlor may be similarly classified.

The required dosages of the all purpose insecticides have ranged from one to ten pounds active ingredient per six inch acre (0.5 to 5 p.p.m.) depending on species of arthropod. Thorough and deep distribution of the toxicant appears to be necessary for the control of most species studied.

Cooperative studies with various departments of Oregon State College include flavor and residue tests on produce grown in treated soil, the effect of insecticides on soil microorganisms and the application of toxicants to and into the soil.

It is concluded that effective and economical control of many soil pests is possible with residual soil insecticides, but many problems require a solution before their effect on agriculture can be determined.

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Some Effects of DDT on Spider Mites

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There has been much conjecture concerning mite build-up and the relationship of these increases to DDT. This study was initiated in an attempt to find out what takes place when the mites come in contact with DDT residues. It was soon discovered that the problem involves many interrelated factors, some of which are discussed in this paper. The fact that DDT causes a dispersion of the mites seems to be an important factor in this problem, and may in some cases be the major cause of the mite build-up.

The literature contains numerous reports of spider mite build-up in conection with DDt applications. Some of the earlier reports were made by Steiner *et al.* (1944) and by Gunthart (1945). The causes of these increases are usually attributed to an adverse effect on predators, although some workers, notably Huffaker and Spitzer (1950) minimize the effect of DDT on predators as causing these increases. Still other workers have questioned the existence of a mite build-up with the use of DDT.

The spider mite used in these experiments was initially identified as *Tetranychus bimaculatus* Harvey by E. A. McGregor, but since has been described as *Tetranychus multisetis* McGregor. The habits of this species were compared in detail with those of *Tetranychus bimaculatus* with the result that it seems highly probable that most of the information contained in this paper will apply to both species.

For most phases of the work the mites were reared on ripe banana squash fruit, and where necessary, barriers of petroleum jelly were used to prevent the mites from leaving the host or from traveling from one treatment to another. Some of the mites were raised in the open on the banana squash while in other phases of the work they were confined within small felt cells covered with transparent plastic and held to the surface of the squash with scotch tape.

The treatments were applied to the squash by dissolving pure DDT in acetone and spraying it on the squash with an atomizer. The untreated checks were sprayed with pure acetone in a volume equal to that used on the treatments. The rate of treatment is given in milligrams of actual DDT per square centimeter of squash surface. In order to correlate this dosage with a possible field application, a banana squash was treated with 2 pounds of 50 per cent DDT per 100 gallons of water. The amount of DDT per square centimeter was then determined. It was found that 0.05 mg. of DDT per sq. cm. is approximately equivalent to a treatment with 2 pounds of 50 per cent wettable DDT per 100 gallons. This amount of DDT is based on a very thorough drenching and complete coverage and is probably greater than that which would be obtained in a standard treatment.

Counts were made with a binocular microscope. All the mites were counted in the felt cells, while the mites on the open surface of the squashes were sampled by counting the mites in 4 millimeter wide strips around the squash. Sufficient samples were observed on each squash to insure a sampled area in excess of 5.0 per cent of the total surface area.

NUMBER OF EGGS.—A fact discovered early in the investigations, and subsequently reported by Wingo & Thomas (1948), is that mites lay considerably fewer eggs in the presence of DDT than they do on an untreated surface. The experiments carried on by Wingo & Thomas were under field conditions, while those here were under controlled laboratory conditions. The extent of the decreased egg production varied under the conditions of the two experiments, but the trends are the same, and the existence of a decreased egg production is clear and definite.

This lowered egg production was first noted in an experiment where a number of 40 sq. cm. areas were marked off on the squash and treated with various dosages of DDT. There were from two to five of these areas in each of the treatments. Twelve young adult female mites were place in each of these areas and the number of eggs counted at the end of a three day interval. The results of this

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Table 1.—Effect of DDT on oviposition of spider mites kept on banana squashes for a 3-day period at 20 to 24° C.

Mg. DDT per Sq. Cm.	Female Mites		Eggs in 3 Days	Average Eggs per Day per Mite	
	At Start	After 3 Days		Based on Original Number of Females	Based on Remaining Number of Females
None	60	56	334	1.86	1.99
0.0042	48	22	106	0.74	1.61
0.0083	48	27	138	0.96	1.70
0.0250	24	17	55	0.61	0.86
0.0500	24	16	40	0.56	0.83
0.1000	24	16	36	0.50	0.75
0.2000	24	9	+30	0.42	1.11

experiment are given in table 1. It can be seen that there is a very definite relation between the amount of DDT used and the extent of the lowered egg production. There was also an increased activity of the mites on the treated surfaces which resulted in many of the mites becoming entangled in the petroleum jelly. This resulted in some slight discrepancies in the results. In order to offset some of the possible error, the number of eggs per female is calculated on the basis of both the original number of females placed on the squash. and those remaining on the squash. In most cases the trend is the same regardless of which method is used to calculate the results. Actually the correct oviposition rate is somewhere between the two figures. The last dosage given, which approximates 4 pounds of actual DDT per 100 gallons, resulted in some actual mortality of the mites. This may partially explain the higher oviposition rate in the heavy treatment when calculated on the basis of the remaining females, as the DDT required about 2 days to kill the mites during which some eggs were laid.

This experiment was repeated with one variation, namely that instead of a 3-day period of observation, there was a 20-day period. Contrary to expectations, there was very little drop in egg production on the treated areas when the 20 day period was taken as a whole. The experiment was designed, however, so that the egg production could be determined at 5-day intervals. Upon breaking the experiment down into 5-day periods, it could be seen that there was a decided drop in egg production on the treated areas during the first such period, but practically no drop during the remaining 15 days.

From this information showing that the drop in egg production occurred during the first few days only, an intensive investigation using individual female mites in felt cells was conducted. The mites were taken as newly emerged females and placed on a recently treated banana squash. The egg production was counted at the end of 4 days and the mites then transferred to new cells. After another 4 days the eggs were again counted and the mites transferred, then finally an egg count was made at the end of a 3-day period. The earlier results were verified by this experiment, and the results are given in table 2. During the first 4 day period there was the expected drop in egg production, but during the second 4 day period the egg production increased greatly, and by the final 3 day period the egg production was essentially equal to the check in both treatments.

It becomes apparent, therefore, that not only is the reduction in egg production temporary on the DDT treated squash but that there is some tendency for the reduction to be longer lasting on the heavier treatment. The question then arose, does the egg production increase on the treated surface due to the weathering of the DDT or the mites becoming acclimated to the DDT. Therefore, after

Table 2.—Effect of DDT on average eggs per day per female in relation to time mites were placed on treated surface at 20–24° C.

Mg. DDT per Sq. Cm.	Days from Start of Experiment								
	0–4			5–8			9–11		
	No. Mites	No. of Eggs	Eggs per Day per Mites	No. of Mites	No. of Eggs	Eggs per Day per Mites	No. Mites	No. of Eggs	Eggs per Day per Mites
None	120	576	1.20	105	538	1.28	26	96	1.23
0.0075	54	162	0.75	42	203	1.21	19	69	1.21
0.0150	71	226	0.79	47	211	1.12	20	72	1.20

Table 3.—Effect of DDT on daily oviposition rate of newly emerged females which were transferred to squash as quiescent deutonymphs.

MG. DDT PER SQ. CM.	NUMBER OF FEMALES	AVETAGE NUMBER OF EGGS PER DAY PER FEMALE				
		1st	2nd	3rd	4th	Average for 4 Days
None	63	0.33	1.46	2.14	2.33	1.56
0.015	51	0.10	0.53	1.24	1.88	0.94
Per Cent reduction from check		69.7	63.7	42.1	19.3	39.7

a month's time the experiment was repeated on the same squash without retreatment. The results were essentially the same a month after treatment as they were immediately after treatment. The reduction in egg production was not quite as great, but in all other respects the results were comparable.

In order to gain additional information concerning the first few days after the mites are placed on a treated surface, the previous experiment was repeated using daily transfers instead of 4 day periods. Table 3 shows the daily oviposition rates of a series of females on treated and untreated areas of the same squash. These females were placed on the squash as quiescent deutonymphs so the first 24 hours was spent largely in a pre-oviposition period. The females in the check showed a normal increased rate of oviposition during the first few days of egg laying life. The mites on the treated areas laid very few eggs the first two days, but the oviposition rate increased rapidly on the third and fourth days. As indicated in earlier experiments, the reduced egg production is shown to be greatest immediately after the mites are placed on a DDT treated surface.

To conclude this phase of the work, several of the preceding experiments were repeated using female mites which were raised on DDT treated sources instead of from untreated sources. In all cases where mites from a treated source were placed on either treated or untreated surfaces there was no drop of any significance in the egg production. This fact seems to substantiate the theory that the drop in egg production, and the subsequent increases, is due to an initial irritation or stimulation of some sort which is followed by an acclimation to the DDT. The weathering of the DDT is apparently of minor importance in this process of adjustment.

From observations made on the mite activity during this initial contact with DDT, it was noted that there was an undue activity of the mites. This activity will be discussed in detail later, but in respect to egg production, it seems highly probable that this is an important factor. It is believed that the lower egg production is associated with the fact that the mites do not settle down to feed and to lay eggs, and is not due to a direct effect on the ability of the mites to lay eggs.

MORTALITY OF MITES.—There was some mortality of the mites which seemed to be directly associated with the DDT. The mites were not able to survive and reproduce satisfactory in dosages of around 0.20 mg. of DDT per sq. cm. This fact is indicated in table 1. Another example of mortality was noted during the single mite transfers. The mites had been raised on an untreated squash and were placed in felt cells on both treated and untreated surfaces. These mites were transferred as quiescent deutonymphs. Of 23 quiescent female deutonymphs placed on a surface treated with 0.03 mg. of DDT per sq. cm., 13 died within the first 36 hours, and 6 more died after becoming adults, but without laying eggs. In contrast, out of 19 quiescent female deutonymphs placed on an untreated squash, all except four matured and layed eggs. A similar mortality was not shown when adult females were transferred.

There was a slight tendency for more non-viable eggs to be produced on DDT treated surfaces. With the lower concentrations of DDT the differences were not significant, but the differences was significant when the dosage reached 0.12 mg. of DDT per sq. cm. The average number

Table 4.—Longevity of adult female mites on a banana squash which had one end untreated and the other end treated with 0.03 mg. of DDT per sq. cm.

Days from Start of Experiment	Number of Females Present	
	Treated	Untreated
Start	50	50
4	50	50
14	46	45
19	34	37
22	5	13
26	0	9
30	0	1

of non-viable eggs on the check was 3.16 per cent while on this high dosage the per cent was 4.59.

Although mites on a DDT treated surface continued their normal egg production and feeding activities, there was definite evidence that their life span was shortened. Table 4 shows the life span of 50 newly matured females on an untreated squash surface as compared to 50 mites on a treated surface. During the first 2 weeks there is no significant difference between the numbers of surviving mites, but after the nineteenth day the mites on the treated surface died rapidly, while those on the untreated surface tapered off gradually.

Repelling or Irritating Effect of DDT.—It was noted fairly early in the experiments that mites tend to show an aversion to areas treated with DDT. This tendency can be noted in table 1 where 56 out of 60 females remained on the checks, but on the treated areas only 107 out of 192 stayed on the squash. From this initial indication a number of experiments were conducted for the purpose of determining to what extent this tendency existed.

A series of female mites was placed in felt cells on banana squashes and periodically the cells were examined for the number of mites remaining unsettled. This experiment was conducted on one squash which was treated 7 days before the experiment, and another which was treated 30 days previously. The results of these observations are summarized in table 5. There were usually some mites wandering around even on the untreated surface, but with the more recent treatment there were consistently more unsettled individuals. With the older treatment this

Table 5.—Per cent of mites remaining unsettled at various lengths of time after being placed on treated and untreated squashes.

Time Lapse in Hours Commencing at 10:30 A.M.	Per Cent of Mites Remaining Unsettled		
		Treated 0.03 mg. DDT per sq. cm.	
	Untreated 55 Females	Deposit 7 Days Old 30 Females	Deposit 30 Days Old 25 Females
0:20	10.9	30.0	20.0
0:35	7.3	36.7	20.0
0:50	5.5	36.7	16.0
1:10	7.3	33.3	8.0
1:25	5.5	36.7	12.0
1:40	7.3	30.0	16.0
1:55	7.3	20.0	20.0
2:10	14.5	27.7	24.0
2:25	3.6	20.0	0.0
2:40	1.8	27.7	16.0
3:00	5.5	36.7	12.0
3:15	5.5	23.3	8.0
3:30	18.2	30.0	12.0
3:45	10.9	33.3	8.0
4:00	7.3	40.0	8.0
5:00	7.3	23.3	12.0
6:00	3.6	16.7	12.0
7:00	3.6	20.0	4.0
24:00	1.8	30.0	8.0

increased activity was not so pronounced, but the tendency was still present. The average percentage of unsettled mites over the entire experiment was 6.83 per cent in the check, 28.95 per cent in the week old treatment, and 13.23 per cent in the month old treatment. There was a tendency for the mites to be quieter after the first hour or two, but this tendency was not very strongly developed.

An attempt was made to determine the distance and rate of travel of the mites after they are placed on the squash prior to the time they settle down. Individual females were placed on the squash and the distance traveled was determined by a map measurer. A mite was not considered to have settled down until it settled down to stay in one spot and feed for a period of at least three minutes. An effort was made to keep the temperature and light comparable for the series of measurements for both treated and untreated surfaces. The same squash was used in both cases in order to eliminate the differences between squashes. Table 6 shows a summary of the results obtained. Not only was the time required to settle down and the distance traveled greater on the treated surface, but the rate of travel was almost

doubled. The increased activity of the mites is very clear cut, and is not confined to merely a slight tendency.

DDT seemed to keep the mites in a restless state for some time, and during this period the traveled faster than the mites on an untreated surface. This tendency is so great that mites attempted to cross barriers of petroleum jelly, and were subsequently trapped. Ordinarily few mites crossed these barriers on untreated squashes. This undue activity, due to DDT, resulted in the mites tending to congregate on the untreated and lightly treated areas. At several times during the experiments untreated areas were left at scattered locations on treated squashes. Almost invariably when the mites were placed on these squashes they would settle in greater numbers on these untreated areas. This tendency also resulted in the mites becoming well scattered over treated surfaces, apparently in an attempt to locate areas free from DDT. However, if forced to, mites can settle down on a treated surface with comparatively little harmful effect.

The end result of the mites scattering to search out untreated surfaces, is a widely scattered population rather than the typical dense colony of the spider mites of the genus *Tetranychus*. On the surface it may seem that the concentrated population should be the perferred condition, but actually there are certain advantages to the dispersal of the colonies. Two sets of experiments were designed to check the population trends of mites under crowded and under sparse conditions. The results of these experiments are included in another paper which has been submitted for publication. Briefly the results are as follows. The egg production per female mite is about three times as great where there is ample space and feeding conditions, than it is where there are extremely dense colonies and poor feeding conditions. Also the percentage of nonviable eggs increases greatly as the feeding conditions become unfavorable.

This dispersal of the mites resulting from the use of DDT is one of the factors involved in the mite build-up when this chemical is used. There is no method of measuring the relative importance of this influence, but under laboratory conditions it was very important.

To understand the situation one must consider the normal mite colony and the means by which it grows and develops on a host. Early in the season female mites crawl up on the host to start a few scattered colonies. These colonies spread almost entirely by an expansion at the perimeters, which means that at all times there is a very dense colony with only mites at the edges living under conditions which have an ideal food supply. The advantages of this concentrated colony seem to be centered in the protective webbing.

Whenever DDT is used, however, the colony as a whole acts differently. The mites instead of remaining in the concentreated mass, disperse to a large degree causing a large number of scattered small colonies to become established. This allows reproduction at full potential for a considerably longer period than would normally occur. The maximum number of mites which the host will support is therefore reached earlier than would have been the case on an untreated surface.

EFFECT OF DDT ON PREDATORS.—There has been a controversy going on for some time as to the value of predators in mite control, and whether DDT would kill enough of these predators to cause a population build-up.

During the course of these experiments there were three cases of mite control by predators. The first was the control of *Tetranychus bimaculatus* by *Orius tristicolor* (White) in a field of lima beans at Woodland, California. The second case

Table 6.—Comparative activity of female mites on treated and untreated surfaces of banana squash.

TREATMENT	NO OF MITES	DISTANCE TRAVELLED IN CM.			TIME TO COME TO REST IN MINUTES			RATE OF TRAVEL IN CM. PER MINUTE		
		Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
Untreated	22	1.00	102.0	13.20	0.50	17.50	5.34	0.60	6.86	2.71
0.015 mg. DDT per sq. cm.	23	0.50	140.0	40.84	0.20	18.00	10.66	0.88	9.60	5.02

was on walnut trees at Linden, California where *Stethorus picipes* Casey reduced a mixed infestation of Pacific mite and European red mite. Lastly *Scholotrips sexmaculatus* (Perg.) contaminated and nearly eliminated some of the present cultures.

The numbers of mites consumed by many of the predators is listed in the literature. Fleschner (1948) lists *Stethorus picipes* Casey as feeding on 486 citrus red mites during its larval development. Ewing (1914) states that one *Hemerobius pacificus* Banks ate 897 mites in 20 days. McGregor & McDonough (1917) state that *Orius insidiosus* (Say) ate an average of 28.88 mites per day as an adult, and 33.16 per day as a numph. The same authors list six nymphal *Scolothrips sexmaculatus* (Perg.) as feeding on 232 eggs plus 5 nymphs and adults during ten days. Some experiments were conducted in the present studies with results similar to the above.

The next point of discussion is the effect is the effect of DDT on these predators. Gunthart (1945) records all stages of *Stethorus punctillum* Weise, as being killed by one per cent DDT. The recently emerged adults were found to be the most sensitive. He also noted that *Oligota pusillima* (Grav.), *Anthocoris nemorum* Linn. and *Orius minutus* (Linn.) were destroyed by the treatment.

Some laboratory tests were conducted to test the sensitivity of *Stethorus picipes* Casey and *Orius tristicolor* (White) to DDT. The tests were conducted by treating petri dishes with measured amounts of DDT dissolved in acetone. The DDT formed an even coating on the surface of the petri dishes. The insects to be tested were placed in the petri dishes, covered and kept at room temperature. The predators were kept without food for the length of the experiments. Table 7 shows the results with *Stethorus* and *Orius*. In the case of both insects, there was a semiparalysis and sluggishness after about 23 hours. By the end of two days nearly all the predators were dead in the treated petri dishes, while most of the *Stethorus* and about half the *Orius* were still alive in the checks.

The conclusions reached are, therefore, that the predators are important in limiting, if not controlling, mite populations. Also some of the major predators are susceptible to DDT poisoning. Mite increases following the use of DDT are at least partially explained by the killing of predators. This factor must be included along with the dispersal of the mites as a factor in mite build-up.

SHORTENED LIFE CYCLE.—Many workers have suggested the possibility of DDT shortening the life cycle by some sort of stimulation. A number of experiments in this study were directed toward an investigation of this possibility. All of the work, with the exception of one experiment, showed negative results in this regard. In this one series of experiments extremely dilute dosages of DDT were used and there was some indication of a stimulation. Upon repeating the experiment, the stimulation was not noted. The mites in this experiment were allowed to lay eggs for a period of 24 hours on squashes treated with various concentrations of DDT. Thirteen days later a complete count of all mites was made, and the numbers present of each life stage were noted. Some newly laid eggs were present, but these were not counted because they were laid by the new generation of females and not by the original parents. The results of the experiment are given in table 8. The lengthening effect of large dosages of DDT on the life cycle was apparent in many phases of the work, but this was the only case showing a shortened life cycle due to the light doses.

POPULATION TRENDS WITH THE USE OF DDT.—The observations made by studying the mite activity, are borne out by a study of the colony as a whole. These studies were made in the absence of predators. A number of squashes were used in which the two ends were separated by a ring of petroleum jelly. Each squash received different treatments on the two ends. The populations were sampled periodically and the squashes receiving the same over-all treatments were grouped together and the average population per square centimeter calculated. These average populations were then plotted for a period covering about a hundred days. Some of these graphs are included in this paper. Figure 1 shows the population trends on four squashes in which one end was treated with 0.0015 mg. of DDT per sq. cm., and the other end was left untreated. The population on the untreated

Table 7.—Number of *Stethorus picipes* Casey and *Orius tristicolor* (White) remaining alive when exposed to DDT deposits on petri dishes.

Time in Hours from Start	Mg. of DDT per Square Cm.											
	Untreated			0.015			0.03			0.06		
	Stethorus	*Orius*		*Stethorus*	*Orius*		*Stethorus*	*Orius*		*Stethorus*	*Orius*	
	Adults	Adults	Nymphs	Adults	Adults	Nymphs	Adults	Adults	Nymphs	Adults	Adults	Nymphs
Start	24	13	9	22	14	11	23	16	10	22	17	13
5	24	12	8	20	12	8	22	13	7	19	15	10
17	23	—	—	14	—	—	17	—	—	15	—	—
23	21	9	5	10	1	5	13	2	3	6	0	2
29	21	8	3	5	0	2	8	0	1	6	0	0
50	19	7	3	0	0	1	0	0	0	0	0	0
72	—	4	0	—	0	0	—	0	0	—	0	0
120	—	2	0	—	0	0	—	0	0	—	0	0

Table 8.—Percentage of each stage present 13 days after egg deposition, in a population held at room temperature and reared on squashes treated with DDT.

Mg. DDT per Sq. Cm.	Number of Individuals	Per Cent Larvae	Per Cent Nymphs	Per Cent Adults
None	278	1.8	8.4	89.8
0.003	146	0.0	0.0	100.0
0.006	165	0.0	2.4	97.6
0.015	48	4.2	4.2	91.6
0.030	41	4.8	9.6	85.6
0.060	56	7.2	14.3	78.5
0.120	82	17.1	14.6	68.3

areas started to build up first, but is soon overtaken by the populations on the treated ends. The initial lag on the treated ends is unquestionably due to the initial lowered egg production due to DDT. The eventual rapid build-up is probably due to increased reproductive potential due to dispersion.

Figure 2 shows the results obtained from five squashes in which one end was treated with 0.06 mg. of DDT per sq. cm. and the other end was untreated. In this case the population in the check built up first and declined first. This is probably caused by a combination of lowered egg production and lengthened life cycle due to the heavy application of DDT. The treatments between these two extremes showed trends which were intermediate. With a treatment of about 0.0075 mg. of DDt per sq. cm. the peak was reached at about the same time as the check. This is shown by figure 3. The rate of increase and maximum population density varies slightly with the squashes used in the experiment and with the average room temperature at the time each series was conducted. Each series was conducted at the same time, but different series were often run at widely separated dates.

A comparison of weak treatments with

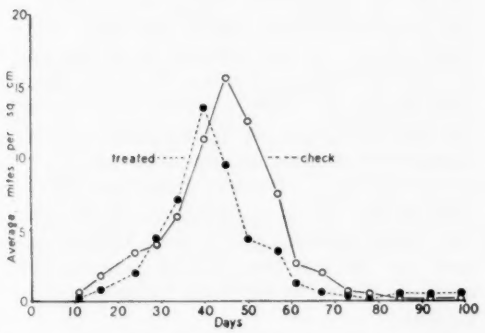

FIG. 1.—Mite build-up and decline on 4 squashes where one end was treated with 0.0015 mg. DDT per sq. cm., and the other end was untreated.

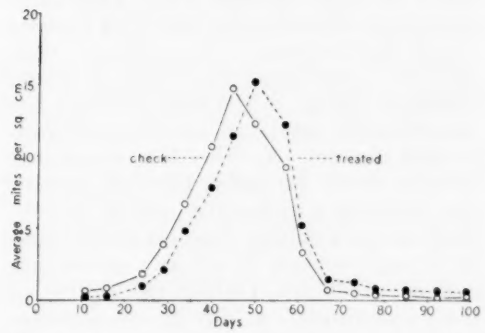

FIG. 2.—Mite build-up and decline on 5 squashes where one end was treated with 0.06 mg. DDT per sq. cm., and the other end was untreated.

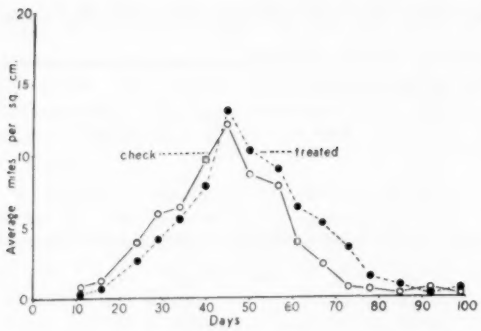

FIG. 3.—Mite build-up and decline on 4 squashes where one end was treated with 0.0075 mg. of DDT per sq. cm., and the other end was untreated.

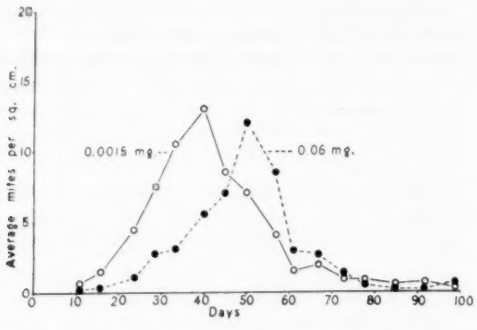

FIG. 4.—Mite build-up and decline on seven squashes where one end was treated with 0.0015 mg. of DDT per sq. cm., and the other end was treated with 0.06 mg. of DDT per sq. cm.

heavy ones, showed considerably more differences in rate of increase than any of the comparisons with the checks. Figure 4 shows the average population trends on seven squashes where one end received 0.0015 mg. of DDT per sq. cm. and the other end 0.06. The difference is about what would be expected based on the relation of the treatments to the checks.

DISCUSSION.—The effects of DDT on *Tetranychus multisetis* is not a simple matter, but instead seems to be an interrelation of several factors acting on both the mites themselves and on the predators. Several points concerning the effect of DDT on the mites are discussed, but the fact that DDT increased the activity of the mites which in turn resulted in dispersion and subsequent mite build-up, is a point which warrants further discussion. In order to understand how this works, one must briefly consider the habits of spider mites.

Early in the spring spider mites emerge from their overwintering habitat and climb on their summer host. This early population is composed largely of females which due to gregarious tendencies congregate in small groups in widely scattered locations. Many of the early colonies are destroyed by predators or other environmental factors. As the few remaining colonies slowly expand in the early season, they develop a protective canopy of webbing. This webbing has been observed by several workers to act as a protection against predators. During the course of these experiments a fully grown *Hemerobius* larva was observed to require 45 minutes to work itself loose from this webbing after becoming entangled while feeding on mites. Due to the density of the colonies, the mites live under conditions where there is extreme competition for food supply and it has been found that as the population becomes more dense the reproductive potential of the mites becomes less.

When DDT is introduced into the environment, the mites become very active and there is a temporary drop in egg production. Due to this increased activity and an apparent desire to find feeding locations free from DDT, these mite colonies become scattered over the entire host. After a few days the mites apparently become acclimated to the DDT and resume normal feeding and egg production, but now instead of being in a dense colony they are in isolated groups. For a while the mites can now reproduce to their fullest potential as there is little competition for food. Of necessity there is now little or no protective webbing and if there were very many predators this condition would be disadvantageous to the mites, but the DDT has also eliminated many of the predators so the need for the webbing becomes greatly reduced. The end result of dispersion is not a greater seasonal peak in spider mite populations, but rather a speeding up of the mite build-up. Under many conditions this earlier peak population means that the peak population arrives before harvest or before the cold weather, thus causing the mite damage to be more apparent.

There is no way of determining the relative value of this dispersion, as com-

pared to other factors such as predator mortality, in causing mite increases. It is believed, however, that dispersion can be extremely important under certain conditions such as comparatively low dosages of DDT or when the DDT is applied at a time when there are a few well established colonies on a host plant.

SUMMARY.—From the results of these studies on *Tetranychus multisetis* McGregor, it seems that there are several distinct effects of DDT on both the individual mite and on the colonies as a whole.

DDT has an effect on the mites which, for lack of a better term, is called an irritating effect. Shortly after an initial contact with this chemical the mites become highly active and move more rapidly and greater distances. During this period of increased activity there are very few eggs laid, and the mites become widely scattered over the host. This dispersion results in a higher reproductive potential and hence earlier mite build-up. If the dosages are high enough there is an actual mortality of some mites, and an increased length of the life cycle.

Some tests were conducted to determine the effect of DDT on two of the leading mite predators, *Stethorus picipes* Casey, and *Orius tristicolor* (White), and it was found that both of these predators can be easily killed by DDT. A few tests were also made to determine the numbers of mites consumed by these predators.

One experiment showed a slight indication of a shortened life cycle due to DDT, but at present there is too little evidence to be able to draw any conclusions in this regard.

A number of experiments were conducted studying population trends on treated and untreated banana squashes in the absence of predators. The evidence from these studies corroborates the evidence obtained from individual mite studies in that the peak populations on squashes with light treatments is reached earlier than that on either untreated or heavily treated surfaces.

Acknowledgments.—The work on this paper was made possible through the facilities of the University of California at Berkeley. Frequent assistance and suggestions were extended by Dr. A. E. Michelbacher and Dr. A. E. Pritchard of the University.

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ISODRIN (Compound 711)*

The Interdepartmental Committee on Pest Control has approved the word "isodrin" as a coined name for the insecticidal chemical, Compound 711. The name "Isodrin" applies to the pure chemical, 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-endo-endo-dimenthanonaphthalene; the technical grade material shall indicate the percentage of isodrin present.

Further reports and publications should use the common name, Isodrin, in place of Compound 711.

* This page should be inserted in the Entomological Progress Report on Compound 711.

ENDRIN (Compound 269)*

The Interdepartmental Committee on Pest Control has approved the word "Endrin" as a coined name for the insecticidal chemical, Compound 269. The name "Endrin" applies to the pure chemical, 1,2,3,4,10,10-hexachlor-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-endo-endo-dimethanonaphthalene; the technical grace material shall Indicate the percentage of Endrin present.

Further reports and publications should use the common name, Endrin, in place of Compound 269.

* This page should be inserted in the Entomological Progress Report on Compound 269.

Walnut Insect and Spider-Mite Control in Northern California

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University of California, Berkeley

Walnut insect and spider-mite investigations in northern California have been largely conducted on the Payne variety of English walnut. When the investigation was undertaken in 1942 the codling moth, *Carpocapsa pomonella* (L) was considered the most important pest and practically the entire investigation was devoted to a study of this insect. Progress on the control of the codling moth has been reported upon by Michelbacher (1945) and Michelbacher & Middlekauff (1949). The early studies showed that standard lead arsenate could be safely substituted for basic lead arsenate, which substantially increased the effectiveness of control. Also, the seasonal population trend of the codling moth was followed and this resulted in a better timing of spray applications. With the advent of DDT, investigations were conducted to determine whether this insecticide could be safely used in the codling moth control program without resulting in a serious increase in the population of such pests as the walnut aphid, *Chromaphis juglandicola* (Kalt.), frosted scale, *Lecanium pruisosum* Coquillett and spider-mites, principally the European red-spider, *Metatetranychus ulmi* (Koch), and the Pacific spider-mite, *Tetranychus pacificus* McGregor.

Early in the investigation it became evident that the walnut aphid was a serious pest of walnuts. As the codling moth control program improved, more and more time was devoted to an investigation of the walnut aphid and during the past several years this study has received more attention than has the codling moth. The information obtained up to and including 1949 has been reported upon by Michelbacher *et al.* (1950).

Probably the most outstanding feature of the entire investigation has been the demonstration of the importance of considering the entire entomological picture in developing a treatment for any particular pest. It was found desirable to determine, insofar as possible, in what ways the treatment affected other organisms, and if adversely, measures to correct the situation were taken. All effort was directed towards developing an effective integrated control program of the important pests of walnuts which would be free of any serious defects. It was found that successful control depended upon a number of factors. Some of the more important ones include the selection of a suitable insecticide, proper dosage, correct timing, use of suitable equipment of sufficient capacity, thorough coverage, and applications made under favorable weather conditions.

Codling Moth Control.—There is but little question that effective control of the codling moth is based in a large measure upon proper timing of spray applications. For years a study has been conducted in which the rate of development of the nuts of the Payne variety has been correlated with the time that the first brood of codling moth larvae start entering them. It has been found that there is a direct correlation and that the activity of the codling moth and the development of the nuts are apparently equally influenced by weather conditions. This relation is so marked that proper timing of the codling moth spray can be based upon the size of the developing nuts. The ideal time to apply the spray is when the average cross-sectional diameter of the nuts is approximately 0.5 inch. This is just prior to the time that the first brood begins to enter them. The spray date varies with the season and at Linden, in the northern San Joaquin Valley, it may be anywhere from the latter part of April to about May 18. At San Jose, which is located at the southern end of the San Francisco Bay, the climate is more coastal and the spray date is usually about two weeks later than at Linden For most satisfactory results it is important that the spray be applied in ample time to protect the developing nuts from the first brood of caterpillars. A single spray will successfully control the pest for the entire season, if it is timed to reduce the first brood effectively.

DDT proved to be much more effective than standard lead arsenate in controlling

the codling moth. Its use, however, has been associated with increases in the walnut aphid, frosted scale, and spider-mite populations. Frequently the population of one or more of these pests develops to a highly destructive level following applications of DDT. Some of the problems involved have been reported upon by Michelbacher & Middlekauff (1949). The walnut aphid problem has been effectively taken care of by incorporating a suitable aphicide in codling moth sprays that contain DDT. Satisfactory control of the aphid, however, can only be obtained where the sprays are carefully and thoroughly applied. This is considered more fully in the section on aphid control.

The danger of serious increases in the frosted scale and spider mite populations has been fairly well eliminated by reducing the concentration of the DDT in the spray to the lowest possible level that will insure effective control of the codling moth. With conventional sprayers the safe level under all conditions so far encountered has been 4 oz. of actual DDT per 100 gallons and for air-carrier sprayers the dosage is 4 pounds of actual DDT per acre. Extensive investigations have been conducted with both conventional and air-carrier sprayers, and the results obtained with each of these methods will be considered separately.

Conventional sprayers.—The sprayers used had 25-foot towers equipped for automatic spraying. The treatments were applied at a pressure of 600 pounds. There were 18 trees to the acre, and to insure good coverage each tree was circled. Approximately 55 gallons of spray were applied per tree. Treatments investigated contained standard lead arsenate, DDT or combinations of these materials. Only single spray programs were investigated and the treatments and the per cent of infested nuts in the harvested crop for the years 1949 to 1951 are given in table 1. It is clear that the treatment which contained one pound of 50 per cent DDT wettable powder per 100 gallons was more effective than the one which contained 3 pounds of standard lead arsenate to the 100 gallons. However, in those years where environmental conditions were favorable for mite activity, there was a larger increase in the mite population in the plots treated with one pound of 50 per cent DDT than those treated with 3 pounds of standard lead arsenate to the 100 gallons. Although the difference was noticeable, it was much less than that which occurred in previous years where larger dosages of DDT were used.

In 1948 experiments were conducted in which one-half pound of 50 per cent wettable DDT powder was combined with 3 pounds of standard lead arsenate per 100 gallons. This treatment resulted in excellent control of the codling moth, without resulting in any apparent increase in the spider-mite population over that which occurred where standard lead arsenate was used. The per cent of infested nuts in the harvested crop where the combination was applied was 3.20 per cent, as compared to 4.36 per cent for the standard lead arsenate treatment and 44.25 per cent for the check. The one-half pound 50 per cent DDT wettable powder, 3 pound standard lead arsenate spray has been investigated during the past three years, and after four years of test-

Table 1.—Relative effectiveness of one spray codling moth control program where applications were made with conventional sprayers just prior to first brood caterpillars entering developing walnuts, at Linden, California.

TREATMENT[1] (Insecticide per 100 gallons)	PER CENT INFESTED NUTS IN HARVESTED CROP		
	1949	1950	1951
Check	17.5	3.58	3.22
Lead arsenate, 3 pounds Safener, 1 pound Oil, 0.33 gallon	5.05	1.10	—
Lead arsenate, 3 pounds Safener, 8 oz. DDT, 8 oz. Oil, 0.33 gallon	2.30	0.20	0.50
Lead arsenate, 2 pounds Safener, 8 oz. DDT, 8 oz. Oil 0.33 gallon	—	0.40	0.60
Lead arsenate, 24 oz. Safener, 8 oz. DDT, 9 oz. Oil, 0.33 gallon	—	0.30	0.30
DDT, 1 pound Depositor, 0.33 lb. Oil, 0.33 gallon	1.60	0.55	—

[1] Lead arsenate, standard lead arsenate; DDT, 50% wettable powder; safener, a commercial basic zinc sulfate product containing 50% zinc expressed as metallic; oil, light summer oil emulsion containing 80% oil.

Table 2.—Relative effectiveness of one spray codling moth control programs where applications were made with an air carrier sprayer just before first brood caterpillars begin entering developing walnuts.

TREATMENT[1] (Insecticide in 500 gallons)	GAL. PER A.	PER CENT INFESTED NUTS IN HARVESTED CROP		
		1949	1950	1951
Check	—	17.5	3.58	3.22
Lead arsenate, 30 pounds Safener, 10 pounds Depositor, 3 pounds Oil, 3 gallons	400	10.8	—	—
Lead arsenate, 60 pounds Safener, 20 pounds Depositer, 3 pounds Oil, 3 gallons	200	8.9	—	—
Lead arsenate, 30 pounds Safener, 5 pounds DDT, 5 pounds Depositor, 3 pounds Oil, 3 gallons	400	—	2.10	0.90
DDT, 10 pounds Depositor, 3 pounds Oil, 3 gallons	400	2.2	0.80	0.25
DDT, 20 pounds Depositor, 3 pounds Oil, 3 gallons	200	4.1	0.50	0.40

[1] Lead arsenate, standard lead arsenate; DDT, 50% wettable powder; safener, a commercial basic zinc sulfate product containing 50% zinc expressed as metallic; oil, light summer oil emulsion containing 80% oil.

ing no evidence of its increasing the spider-mite problem has been obtained. The treatment has always resulted in better control than obtained with standard lead arsenate, and has averaged about as good as a treatment of one pound of 50 per cent wettable DDT powder to the 100 gallons. Studies in 1950 and 1951 were conducted in which the amount of standard lead arsenate used in the DDT-standard lead arsenate mixture was reduced from 3 to either 2 pounds or 24 oz. to the 100 gallons. As seen from table 1, reducing the amount of standard lead arsenate had little effect upon the degree of control obtained.

From 1948 to 1951 inclusive there has been a marked reduction in the per cent of infested nuts in the check trees. The trend for the past three years is shown in table 1. It is possible that the reduction has in part been due to a general improvement in the control of the codling moth in the orchard where the experimental investigations have been conducted. Although this may be the case, ecological factors are known to exert a marked influence on the size of codling moth population. Some of these have been discussed by Michelbacher *et al.* (1950, 1951).

Air-carrier sprayer.—This type of equipment has been under investigation for the past four years. The treatments and the per cent of infested nuts in the harvested crop for the years 1949 to 1951 inclusive are given in table 2. Standard lead arsenate applied with air-carrier sprayers has not been nearly as effective as DDT in controlling the codling moth. Best and most consistent results have been obtained where approximately 8 pounds of 50 per cent DDT wettable powder have been used per acre. The control has been about the same whether applied in 200 or 400 gallons of water. In no case was there any indication that this dosage of DDT resulted in an increase of spider-mites, over that which occurred with any other treatment including unsprayed checks. Aircarrier applications of DDT compare favorably with the best conventional sprayer codling moth programs and are more rapidly applied.

WALNUT APHID CONTROL.—The walnut aphid investigations have been directed toward developing a program that will insure effective control of the pest throughout the season. Satisfactory results are possible if effective aphicides and suitable equipment are used. Thoroughness of coverage is essential and with some aphicides good control can be obtained only if they are applied when there is little or no wind.

The walnut aphid hatches from overwintering eggs (Fig. 1). as the buds of the Payne variety begin to push in the spring. The infestation seldom reaches a destructive level before the end of April or early May. Frequently there may be a rather rapid initial rise in the aphid population during April. However, this is usually, but not always, suppressed by natural enemies. Treatment can generally be delayed until the time it is necessary to apply sprays to control the codling moth. Experience has shown that the addition of an aphicide to the codling moth spray is a desirable practice, and this is a must where DDT is used in the codling moth program.

Addition of Aphicides to the Codling Moth Spray.—Walnut aphid control obtained in 1950 and 1951 where aphicides were used in combination with codling moth sprays applied with conventional sprayers is given in table 3, and similar information for air-carrier treatments is given in table 4. Excellent control for a

Table 3.—Walnut aphid population trend at Linden where aphicides were combined with codling moth spray containing standard lead arsenate and DDT, and applied as thorough coverage sprays with conventional sprayers.

APHICIDE (100 gallons[1])	APHIDS PER LEAFLET ON SURVEY DATES GIVEN, 1950						
Treated May 4	May 3[2]	May10	May 19	June 6	June 13	June 19	June 26
14% nicotine dry concentrate, 1 pound	3.25	0.10	0.26	6.48	18.32	[3]	
25% wettable parathion, 2.67 ounces	2.44	0.00	0.02	0.00	0.14	1.04	1.92
6% gamma isomer BHC, 1 pound	2.18	0.00	0.00	0.06	0.18	0.72	2.24
25% Lindane, 8 oz.	4.86	0.00	0.00	0.04	0.06	0.22	1.44
20% TEPP, 4 fl. oz.	2.48	0.02	0.02	2.46	5.78	[3]	
	1951						
Treated May 12	May 11[2]	May 18	May 28	June 7	June 22	June 30	
25% wettable parathion, 2.67 oz.	11.10	0.00	0.01	0.08	3.63	19.75	
6% gamma isomer BHC, 1 pound	15.22	0.00	0.32	1.28	21.92	68.04	

[1] Applied at the rate of approximately 1000 gallons per acre.
[2] Pretreatment count.
[3] Treated with aphicide.

period upward to six weeks or longer can be expected. Where the sprays were applied with conventional sprayers BHC and parathion proved to be more effective than nicotine and tetraethyl pyrophosphate. With the air-carrier applications, parathion, benzene hexachloride and nicotine all resulted in good control, with parathion being slightly more effective.

Late Season Aphid Control.—Usually more than a single treatment is necessary to control the walnut aphid for the entire season. However, in many cases it should be possible to obtain satisfactory control with not more than two applications. Some of the more important factors having a bearing on aphid control are: choice of insecticide, type of equipment, community action, and weather conditions.

Choice of Insecticide.—To the present time best control has been obtained with parathion. Investigations have shown that this insecticide at relatively low dosages has greater latitude both in regard to equipment and weather conditions than any other insecticide so far commercially used in the walnut aphid control program. Tetraethyl pyrophosphate has been effectively used but its limitations in so far as satisfactory control is concerned are greater than those associated with parathion. Excellent control has been obtained with the experimental material EPN 300 where it has been applied at the rate of 4

Table 4.—Walnut aphid population trend at Linden where aphicides were combined with codling moth spray and applied with air-carrier sprayer.

APHICIDE (500 Gallons)	CODLING MOTH PROGRAM	APPROX. GAL. PER ACRE	AVERAGE APHIDS PER LEAFLET ON SURVEY DATES GIVEN						
			1950						
Treated May 2	—	—	May 3[1]	May 10	May 19	June 6	June 13	June 19	June 26
14% nicotine dry concentrate, 9 lb.	Standard lead and DDT	400	4.19	0.00	0.01	0.16	0.23	0.74	2.33
14% nicotine dry concentrate, 9 lb.	DDT	400	5.02	0.00	0.00	0.11	1.00	0.60	1.90
14% nicotine dry concentrate, 18 lb.	DDT	200	5.58	0.00	0.00	0.16	1.58	0.68	2.36
6% gamma isomer BHC, 9 lb.	DDT	400	5.26	0.00	0.00	0.00	0.00	0.24	0.44
			1951						
Treated May 12	—	—	May 11[1]	May 18	May 28	June 7	June 22	June 30	
14% nicotine dry concentrate, 9 lb.	DDT	400	9.58	0.00	0.04	0.42	9.50	16.96	
14% nicotine dry concentrate, 18 lb.	DDT	200	7.22	0.08	0.02	0.32	14.06	40.02	
25% wettable parathion 1.25 lb.	DDT	400	4.72	0.00	0.00	0.00	0.14	3.80	
25% wettable parathion, 2.5 lb.	DDT	200	6.84	0.00	0.00	0.00	0.14	2.72	
6% gamma isomer BHC, 9 lb.	Standard lead and DDT	400	7.66	0.00	0.00	0.10	7.00	25.10	

[1] Pretreatment count.

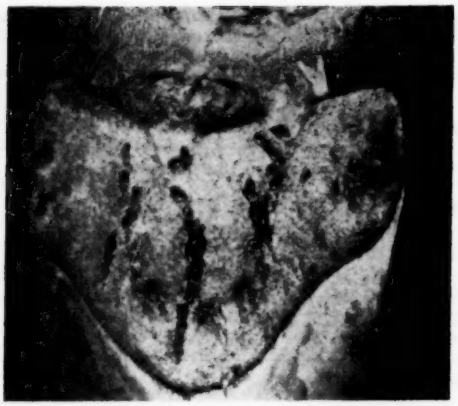

FIG. 1.—Overwintering walnut aphid eggs in cracks of a leaf scar. ×10.

pounds of 27 per cent material per acre. This dosage is approximately four times the required dosage of parathion.

Benzene hexachloride has resulted in effective aphid control. However, its use is limited to applications in the codling moth spray. Investigations have shown that if more than one application is made during a year, or if it is used late in the season, there is danger of its imparting an off flavor to the harvested nuts. Furthermore, satisfactory control will not result if it is applied under windy conditions.

Nicotine, which is still used, was once the most important aphicide in the walnut aphid control program. Investigations with this insecticide have been continued, and where applied under ideal conditions and with suitable equipment satisfactory control is possible. Effective control in a large measure is based on natural enemies destroying any aphids that escape treatment. Therefore, where these have been killed by treatments of DDT, benzene hexachloride, tetraethyl pyrophosphate, or parathion and sufficient time has not elapsed for them to become established again, a rapid increase in the aphid population can be expected, even though the nicotine was applied under favorable weather conditions. So far the only exception to the above statement is where nicotine has been applied with an air-carrier type of sprayer of sufficient air capacity. Even here, for effective control, it is necessary that the treatment be thoroughly applied and this is only possible under ideal weather conditions.

Choice of Equipment.—Any equipment used should have sufficient capacity to insure thorough coverage. When used at the proper dosage the newer insecticides which are now in commercial use such as parathion, tetraethyl pyrophosphate, and benzene hexachloride should result in a kill of aphids so complete that following treatments no live aphids can be found. Therefore, unless the equipment available, whether it be a conventional sprayer, air-carrier sprayer, airplane, ground duster, or smoke machine, can meet the above requirement, it should not be used, Unless the aphids are all but eliminated they are likely to create a troublesome problem. The newer insecticides are very destructive to natural enemies, and in their absence a small aphid population can increase to a highly destructive level in a relatively short time. Field observations have shown that in the absence of natural enemies the aphid population doubles about every three days. At this rate of increase a population averaging only one aphid per leaflet will have increased to 8 in nine days or 32 in 15 days. Where control approaches eradication a long period of protection can be expected, and when the aphid does start to increase sufficient time has usually elapsed so that natural enemies have an opportunity to reestablish themselves in the orchard. Even under these conditions, the aphid population, if no further treatment is applied, might rise to a destructive level but it is almost certain to be checked by natural enemies before the trees drip with honeydew. Any damage that occurred would be much less than that resulting where the initial aphid control was unsatisfactory.

Frequent treatments for aphid control are undesirable not only because they are expensive but also because they have an adverse action upon the natural balance. This not only affects the aphid but other pests such as spider-mites and scales. Although no experimental evidence has been found to prove that ineffective aphid control is associated with the increase in the importance of the spider-mite problem, observations indicate that there may be some connection between the two. It has been pointed out frequently that the mite condition that exists in a treated orchard is not as serious or no worse than that occurring in an adjacent one that has received no treatment. In some cases it is questionable whether it is safe to

assume that the orchard was actually untreated, for if smoke machines using tetraethyl pyrophosphate have been used. there is a good chance that a smoke drift may have passed through it. If this occurred it is conceivable that the effect upon the natural balance might have been devastating. It is known that an insufficient dosage of an insecticide such as tetraethyl pyrophosphate can be very harmful and rapid increases in the aphid population have followed poor kills.

With air-carrier sprayers having sufficient air capacity, excellent aphid control has been obtained with the following dosages of insecticides applied in 50 gallons of water per acre: 25 per cent wettable parathion, 1 pound; or tetraethyl pyrophosphate, 40 per cent 12 to 16 oz.; or 14 per cent nicotine dry concentrate 7 to 9 pounds.

Aphid Control Simplified by Community Action.—There is no question but that the aphid problem would be less severe if all growers in a locality practiced efficient control. Heavily infested orchards in a region will increase the problem of aphid control in nearby orchards. This is particularly true if effectively treated orchards are to the leaward side. Migration of winged aphids from heavily infested orchards can be of considerable proportions. Some measure of the importance of migrating aphids was obtained in the experimental plots at Linden during 1951. The plots under question were treated with parathion applied with an air-carrier sprayer between May 11 and 14. The aphid population increased much more rapidly in the outside 5 rows, which were located across the road from a heavily infested orchard, than it did in the 10th to 15th rows from the orchard. The trend of the infestation following treatment in these two areas is given in table 5. The information clearly shows that the effective period of control was greatly reduced by the influx of migrating aphids. The same effect has been noted in other studies where experimental plots have been adjacent to heavily infested orchards.

SPIDER-MITES.—The Pacific mite and the European red spider on occasions have been destructive to walnuts. Of the two, the Pacific mite is the more important. Injury by these pests has increased during the past several years. Although the damage has not been of alarming proportions, it has been sufficient to create considerable interest in factors that may be responsible for the upsurge. It is possible that the increase in importance of spider-mites is inpart due to natural environmental conditions being more favorable than usual for their development and multiplication, or it may be that in one way or another, some of the control programs directed against the codling moth and the walnut aphid are responsible. Whatever may be the cause, it probably involves a complexity of factors so interwoven that at the present time it is impossible to obtain a clear picture of just what is happening. However, it does not appear that the reduced dosages of DDT used in the codling moth spray programs are responsible for the increase in injury caused by mites.

Table 5.—Influence of aphid migration on the population trend in an orchard receiving effective treatment.[1]

LOCATION	DATE AND AVERAGE APHIDS PER LEAFLET				
	May 18	May 28	June 7	June 22	June 30
Rows 1 to 5	0.00	0.00	0.56	13.82	23.66
Rows 10 to 15	0.00	0.00	0.00	0.14	3.80

[1] Treated with parathion applied with an air carrier sprayer May 11 to 14.

Benzene hexachloride, which is one of the aphicides used to control the walnut aphid, like DDT, will result in an increase in the mite population if used at a sufficiently high dosage. The dosage needed for aphid control is much below the danger level. Yet where it is incorporated in a codling moth spray containing DDT, there is an additive effect of the two materials which approaches a point where a slight increase in the spider-mite population might be expected where environmental conditions are highly favorable to the pest. This, while a factor, certainly does not account for serious increases in the spider-mite population which have recently occurred. In the walnut insect investigations every effort has been made to develop a program which will not result in a serious increase in the mite population. In the experimental plots recommended treatments have performed well. This has been true of both those applied with conventional as well as those applied with air-carrier sprayers. Success in part has been due to thorough application. This has resulted in effective control,

which in turn has reduced the number of applications necessary to control walnut insects for the entire season to 2 or 3. During 1951 mites never approached a destructive level in any experimental treatments. Some light infestation of the Pacific mite appeared after the middle of August and while the population showed some slight increase it was finally completely checked by natural enemies of which the ladybird beetle, *Stethorus*, appeared to be the most important.

Besides the combination codling moth-aphid spray, part of the experimental area received one and the rest two treatments of parathion applied with an air-carrier sprayer at the rate per acre of 1 pound of 25 per cent wettable powder in 50 gallons of water. Where the second application was applied on August 17, it was observed that the treatment resulted in a kill of what few motile spider-mites were present. This suppression of the mite population probably aids in checking the pest and is in substantiation of previous years' findings.

The most outstanding feature of the insect control program has been its effectivenes, which has resulted in few treatments being necessary. The fewer the number of applications, the less is the impact upon natural enemies. In many cases where effective control is obtained, natural enemies are able to reestablish themselves in the orchard again before the pest population becomes destructive. Sometimes they may even be present in sufficient numbers to prevent the pest population from reaching a destructive level. This is in marked contrast to that which occurs where poor control results, making frequent applications necessary. The new aphicides are very destructive to natural enemies, and if repeated treatments are necessary to control aphids, natural enemies may be nearly eliminated from an area. Both parathion and tetraethyl pyrophosphate at proper dosages are effective against active spider-mites but not the eggs. It is almost certain that treatments with these materials that result in poor aphid control will also be ineffective against spider-mites. If this is the case, then increases in mite as well as aphid population can be expected.

The dust deposit from frequent applications of insecticidal dusts used for walnut aphid control can result in serious spider-mite infestations. Large spider-mite populations have occurred where frequent applications of nicotine dusts have been made for aphid control. However, there is no reason why insecticidal dusts should not be used so long as the treatment results in effective control so that frequent applications are not necessary.

Control is possible where serious spider-mite infestations threaten. Experiments conducted by Middlekauff & Michelbacher (1950) showed that very good control of spider-mites could be obtained with a 15 per cent Aramite wettable powder used at the rate of from 1 to 2 pounds to the 100 gallons of water and thoroughly applied with a conventional sprayer. In 1951 successful commercial control was obtained with this acaricide where it was used at the rate of 1.5 pounds to the 100 gallons of water and applied as a thorough coverage spray with conventional equipment.

In order to reduce the danger of spider-mites becoming a serious problem, it is desirable to keep walnut plantings in a vigorous growing condition, and the trees should never be allowed to suffer for want of water.

SUMMARY AND CONCLUSIONS.—A single properly applied spray will effectively control the codling moth for the entire season. It should be applied just prior to the time that first brood caterpillars begin to enter the developing nuts. Investigations have shown that there is a direct correlation between the development of the walnuts and the seasonal activity of the codling moth. With the Payne variety it has been found that the caterpillars do not begin to enter the nuts until the average cross-sectional diameter of the nuts has reached one-half inch. Therefore, spraying can be delayed until the nuts have reached this size.

DDT has been found to be much more effective than standard lead arsenate for controlling the codling moth. In order to avoid a serious increase in the walnut aphid population it should be used in combination with an effective aphicide. Unless used at sufficiently low dosages DDT is also likely to encourage increases in the spider-mite and the frosted scale populations.

Where sprays are to be applied with conventional sprayers probably the most effective mixture to use is as follows:

Standard lead arsenate	2 lbs.
DDT, 50 per cent wettable powder	8 oz.
Safener—a commercial basic zinc sulfate product containing 50 per cent zinc expressed as metallic	8 oz.
25 per cent wettable parathion	2.67 oz.
or	
Benzene hexachloride (6 per cent gamma isomer)	1 lb.
Light summer oil emulsion containing 80 per cent oil	0.33 gal.
Water	100 gal.

With air-carrier sprayers best control of the codling moth has been obtained where DDT, 50 per cent wettable powder, has been applied at the rate of approximately 8 pounds per acre. At this dosage no adverse effect upon the spider-mite or frosted scale has ever been detected. Excellent control of the codling moth has been obtained where this amount of DDT has been applied in either 200 or 400 gallons of water per acre. The mixture per 500 gallons where 400 gallons are applied per acre is as follows.

50 per cent DDT wettable powder	10 lbs.
DDT depositor	3 lbs.
25 per cent wettable parathion	1.25 lb.
or	
Benzene hexachloride (6 per cent gamma iosmer)	9 lbs.
or	
14 per cent nicotine dry concentrate	9 lbs.
Light medium summer oil emulsion	3 gal.

Where 200 gallons are used:

50 per cent DDT wettable powder	20 lbs.
DDT depositor	3 lbs.
25 per cent wettable parathion	2.5 lbs.
or	
Benzene hexachloride (6 per cent gamma isomer)	18 lbs.
or	
14 per cent nicotine dry concentrate	18 lbs.
Light medium summer oil emulsion	3 gal.

The importance of thorough application of treatments can not be overemphasized.

Where used early in the season a single treatment of benzene hexachloride can be applied safely as an aphicide without imparting an off flavor to the harvested nuts. Satisfactory control with this insecticide can be obtained only where it is applied under relatively stable weather conditions.

Aphid control with such insecticides as tetraethyl pyrophosphate, benzene hexachloride or parathion can not be considered satisfactory unless the population is all but eliminated from the orchard. Of the aphicides so far extensively tested, parathion has been found to have the greatest latitude both in regard to weather conditions and equipment used.

For late season aphid control highly satisfactory results have been obtained with air-carrier sprayers, of sufficient air capacity, where the following dosages of insecticides have been applied in 50 gallons of water per acre: 25 per cent wettable parathion, 1 pound; or tetraethyl pyrophosphate 40 per cent, 0.75 to 1 pint; or 14 per cent nicotine dry concentrate 7 to 9 pounds. Where air-carrier sprayers are of low capacity the amount of water used per acre should be increased to 100 gallons.

The aphid problem in any locality can be simplified if all growers involved follow an effective, coordinated aphid control.

Where spider-mites have increased to a destructive level they have been successfully controlled with Aramite 15 per cent wettable powder used at the rate of from 1 to 2 pounds per 100 gallons and applied as a thorough coverage spray.

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Pollination of the Red Clover Flower by the Honey Bee[1,2]

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Discussions on the value of bees in the production of medium red clover seed center about the honey bee, because of the low numbers of bumble bees and other pollinators in many areas where this clover is grown. Although honey bees are now generally recognized as effective pollinatinga gents of red clover and are responsible for a large share of the pollination obtained, apparently some people still believe that only bumble bees can perform this task satisfactorily. This belief is said to be based on the apparent discrepancy between the length of the honey bee's tongue and the depth of the corolla tube of the red clover floret.

The experiments of Westgate & Coe (1915), and of others since that time, demonstrate that red clover from which pollinators are excluded produces practically no seed. In areas where few native pollinators are present, seed is often produced after honey bees have been brought into the fields. Sometimes, when there are other, more attractive fllowering plants nearby, it is difficult to obtain adequate activity on the flowers.

The behavior of the honey bee in visiting the red clover flower, and the manner in which the pollination act is accomplished, seem to be related to the structure of the flower and its attractiveness to the bee. Westgate and Coe (1915), in discussing the structure of the red clover flower, state: "When a bee inserts its proboscis into the staminal tube, it is inserted between the vexillum and the carina. In doing this the carina and alae are pressed downward and the stigma and anthers are thrust up against the bee's head. Since the carina and stamens are elastic, the pollen is thrown with considerable force against the head of the bee. When the bee releases the pressure on the carina and alae, the parts return to their normal position on account of the elasticity of the base of the carina and a small dilated vesicular process at the base of each ala." While this discussion apparently applies to bees in general, the same authors also state: "Our observations and results show that the honey bee is able to spring the keels of red-clover flowers and thereby cross-pollinate them."

In pollination studies on alfalfa in Utah and California, Uansell & Todd (1946) found that it is necessary for honey bees to trip the blossoms before pollen can be collected, whereas nectar can be collected without the blossoms being tripped. They found some bees collecting only nectar, while others collected pollen. Sometimes pollen accidentally collected was discarded by nectar-collecting bees. Unless there was an acute scarcity of other sources of pollen, the bees collected only nectar. A small proportion of the flowers visited by nectar collectors were tripped and pollinated accidentally. In the area about Columbus no honey bees have been observed collecting alfalfa pollen.

The writer has made many observations on the visitation to the red clover flower by honey bees. The worker bee approaches the flower over the keel (carina) and wings (alae) and forces her head down between the standard petal (vexillum) and keel with tongue outstretched. The anterior surface of the head is pushed against the standard petal. The anterior and middle pair of legs clutch and claw at the wings, pulling them and the keel, to which they are attached, away from the standard petal. This enlarges the opening into the corolla tube and trips the sexual parts enclosed in the keel. Considerable force is required to separate these parts and trip the flower, but the honey bee seems to do this easily and without hesitation. The bee extends her tongue as deeply as possible into the corolla each time she visits a blossom, apparently in search of nectar.

When the keel and wings are pulled away from the standard the stigma and anthers are exposed. At this time the bee's tongue and other mouth parts are deep within the corolla and beyond the anthers. No bee was observed to make any effort to collect pollen from the

[1] Presented at the meeting of the American Association of Economic Entomologists at Cincinnati, Ohio, December 10–13, 1951.

[2] In cooperation with the Ohio State University and the Ohio Agricultural Experiment Station.

anthers with her mandibles. The stamens and pistil remain erect and contact the bee on the posterior ventral part of the head where it joins the thorax. Pollen from the anthers is deposited and accumulated in this area, with a large mass building up on the fossa of the proboscis around the bases of the various parts of the proboscis. According to Vansell & Todd (1946), alfalfa pollen collects in the same area, except that they found alfalfa pollen accumulating also on the anterior surface of the bee's head. The red clover pollen accumulated on the fossa has a drier appearance than that farther down on the mentum, where it takes on a translucent aspect, evidently from liquid absorbed from the mouth. Just how this occurs is not known, but the pollen does not appear to enter the mouth.

In contrast to alfalfa, most of the honey bees working red clover blossoms collected pollen, as indicated by pollen on their legs or heads. Some bees also carried nectar, in addition to pollen, commonly in quantities too small for measurement with a refractometer. Frequently no bees carrying nectar could be found. Some beekeepers have reported obtaining surplus honey from red clover, but at no time at Columbus in the 5 years 1947–51 has activity resembling a honeyflow been observed on medium red clover. In this period there have been light to moderate hone flows from alfalfa while the bees were visiting the red clover in satisfactory numbers.

As described above, the bee thrusts her probscis into the corolla as deeply as possible, apparently in search of nectar. The position of the mouth parts and the behavior of the bee in visiting the flower strongly suggests that pollen collection is accidental. Possibly this approach is an indirect method of pollen collection. Even when the bees collect no nectar in their honey stomachs, they continue to visit enough flowers to collect large loads of pollen. Possibly minute quantities of nectar are obtained frequently enough to keep up their activity. Minute quantities might be used entirely by the bee to moisten the pollen or for food while in the field.

The depth of the red clover corolla in relation to the length of the honey bee's tongue appears to be unimportant to mechanics of the pollination act. Since the bee always enters the red clover floret over the keel, tripping the flower and contacting the sexual parts with her head, it is unnecessary for her to reach the bottom of the floret with her tongue. The tongue of the honey bee apparently plays no part in the transfer of the pollen. The location of the sexual parts at the top of the flower places them within easy reach of the bee. Instead of the floret being poorly adapted to honey bee pollination, the corolla tube, which is closed on all sides, without the deep cleft of the alfalfa blossom, is particularly well suited to the honey bee. This structural arrangement induces the bee to enter the flower over the keel, where it is tripped and pollinated. Alfalfa pollination by honey bees might be facilitated if the flower were closed at the base of the keel, as is the red clover flower.

SUMMARY.—In visiting the red clover flower the honey bee approaches over the keel and wings and forces her head down between the standard petals and keel with tongue outstretched, apparently in search of nectar. Pollen is deposited on the posterior ventral part of the head, where it is carried to other flowers.

Most of the honey bees visiting red clover blossoms collected pollen and some collected nectar. The behavior of the bee in visiting the flower suggests that pollen collection may be accidental.

The length of the honey bee's tongue is no handicap in the act of pollinating red clover, because the sexual parts of the flower are at the top and the tongue is not used in transferring the pollen from flower to flower.

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Effect of Insecticides and Other Substances on Oviposition by *Aëdes sollicitans*[1]

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Very few studies have been made, and very little information is available, on the factors influencing oviposition of insects. Particularly is there a paucity of knowledge relative to the stimulation of egg-production. The only naturally occurring substance observed to attract females and to predispose them to oviposit has been ammonia. From his studies. Richardson (1916) concluded that oviposition of the housefly depends largely on the presence of ammonia. Other investigators, have noted the attraction of female houseflies to ammonia. Mehta (1934) observed that *Anopheles subpictus* (Rossi) exhibited a marked tendency to oviposit on waters containing more than 2.5 parts per million of ammonia; whereas, De Coursey in 1931 noted extensive oviposition of the Angoumois grain moth, *Sitotroga cerealella* (Olivier), exposed directly to the fumes of ammonium carbonate. Van Leeuwen (1947) found that there was a marked decrease in the number of eggs produced by the codling moth following a change from old, partly decayed apples to those fresh from winter storage. This suggests that products of decay influence oviposition. Tenhet (1947) observed the impairment of oviposition of cigarette beetles surviving exposure to a spray of pyrethrum in oil and noted that 25 to 68 per cent fewer eggs were obtained.

CONCEPT OF A "DEATH STRESS."—The previous work cited suggests that the presence of ammonia favors oviposition in certain species. Since strong ammonia fumes are quite lethal to mosquitoes, and if oviposition does take place, the phenomenon of "death with oviposition" may be termed a "death stress." This concept implies that anything that kills the mosquito—short of crushing it—would cause oviposition. One can hypothesize that this is a survival phenomenon. Whether this concept is true or not, or whether the oviposition under a "death stress" is due to neurogenic reasons, the conceptions served as a guide in this investigation. Studies were made, therefore, of the effect on oviposition of substances which by the pungency of their vapors could be considered as irritants, and which would produce a "death stress." Since insecticides obviously produce a "death stress," subsequent studies were made of the effect of various insecticides on oviposition.

SPECIES AND AGENTS USED.—*Aëdes sollicitans* (Walker) were collected in the woods far removed from any area under treatment with insecticides. A large test tube fitted with an inverted plastic cone, to prevent the insects from escaping, was placed over each insect as it landed on the collector's clothes. When the tube contained fifty mosquitoes it was emptied into a screened cage. After 800 to 1000 insects had been collected, the cage was returned to the laboratory and placed in an insectary at 80° F. The mosquitoes were fed approximately five per cent sugar water and received blood meals from a guinea pig daily. After seven to ten days' captivity, the insects were treated with the following irritants: ammonia, ether, acetone, ethyl alcohol, quinoline, chloroform, and nitric acid; and the insecticides DDT, chlordane, aldrin, toxaphene, benzene hexachloride, and rotenone.

PROCEDURE FOR CHEMICAL AGENTS.—The irritants were placed in airtight chambers 45 millimeters in diameter by 8 centimeters deep. Ten female adults were exposed in these chambers for varying periods of time. The exposure time varied in order to produce a "death stress" for each irritant just sufficient to immobilize the insects. The achievement of this stress, just short of death, was not possible with all the insects, so that some laid eggs and died, some laid eggs and lived, and some died without oviposition. The exposure time for the various agents ranged from 10 seconds to 120 seconds. The idealized situation was, of course,

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[1] This work is not to be construed as necessarily reflecting the views of the Department of the Navy.

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Table 1.—Chemical agents.

24 Hours Wet 240 Females

	Exposure Time (Seconds)	Number of Eggs	Mean Eggs per Female	σ
Ether	17	157	39	±23
Ammonia water	13	669	45	36
Control	—	385	48	66
Chloroform	10	460	51	44
Ethyl alcohol	123	588	54	43
Nitric acid	63	345	58	71
Quinoline	72	658	66	43
Acetone	63	1349	79	54

Table 3.—DDT.

24 Hours Wet 140 Females
60 Seconds Exposure

	Per Cent Females Ovipositing	Mean Eggs per Female	σ
0.5%	75[2]	83	±35
1.0%	45[1]	81	41
2.0%	65[1]	52[2]	33
3.0%	55[1]	83	68
4.0%	75[2]	74	55
5.0%	40[1]	45[2]	41
Talc control	95	83	43

[1] Significant at the one per cent level.
[2] Significant at the five per cent level.

only partially obtained. Each insect was then transferred to either a separate small vial or a dish and placed in a constant temperature chamber at 79–80° F. In some tests the vials contained moistened cotton stoppers and the dishes contained moistened filter paper to attempt to insulate wet conditions for oviposition. In other tests the containers were maintained in a dry state. The controls were placed directly into individual containers from the holding cages.

Procedure for Insecticides.—The insecticides and various concentrations of DDT were used in the powdered state with talc as the diluent. The various powders were placed in separate 50 ml. flasks which were rotated by hand until a thin coating of the powder covered the entire interior. The excess powder was then removed by inverting the flasks and tapping them on a hard surface. Ten mosquitoes at a time were then placed in one of the insecticide-coated flasks, and the flask rotated by hand for sixty seconds. The time was determined by stop watch. The controls were rotated in the same manner in talc alone. Following the exposure, the mosquitoes were removed by inverting the container over a clean 50 ml. flask. Individual insects were then transferred to separate Petri dishes containing either wet or dry filter paper. This was accomplished by inverting the flask containing the ten mosquitoes over the top of a closed dish containing a quarter inch circular opening drilled in the glass. When one insect entered the dish through the opening, the flask and dish lid (with the hole) was moved to another dish, while the dish containing the single mosquito was immediately capped with a solid top.

Table 2.—Insecticides.

24 Hours Wet 210 Females
60 Seconds Exposure

		Number of Eggs	Mean Eggs per Female	σ
Aldrin	0.25%	311	14[1]	±13
Chlordane	2.0 %	1319	47[1]	29
DDT	5.0 %	908	53[1]	43
Rotenone	2.5 %	1167	69	53
Toxaphene	0.25%	1200	71	56
BHC	0.2 %	1590	84	50
Talc control		2143	89	50

[1] Significant at the one per cent level.

Determination of Egg Production, Viability and Hatch.—The eggs, from the treated and untreated mosquitoes, deposited in the individual containers were carefully counted and tabulated for each insect and each agent. All of the eggs from one run were subsequently maintained on moist filter paper for six days at 79–80° F. to permit embryonic development. They were then immersed in tap water to determine the percentage that would hatch. Viability of the remainder of the eggs was estimated by clearing the chorion with diluted aqua regia (DeCoursey & Webster, 1952) on the thirteenth day after oviposition and examining for the embryonic developmental stage attained. The total number of viable eggs was calculated by adding the number of eggs with observed developed embryos to the actual number that hatched.

Table 4.—Insecticides.

5 Hours Dry 80 Females
60 Seconds Exposure

	Per Cent Females Oviposiing	Mean Eggs per Female	σ
Talc control	0	0	—
Toxaphene 0.25%	30[2]	7	±5
Aldrin 0.25%	30[2]	15	19
Chlordane 2.0 %	70[1]	42[1]	26
Rotenone 2.5 %	80[1]	57[1]	45
DDT 5.0 %	90[1]	89[1]	61
BHC 0.2 %	90[1]	99[1]	60
24 Hours Wet Talc Control	100	112	

[1] Significant at the one per cent level.
[2] Significant at the five per cent level.

Table 5.—Insecticides. Viability and hatch 13 days after oviposition.

24 Hours Wet 70 Females

	Total Eggs	Mean Per Cent Viable	σ	Mean Per Cent Hatch	σ
DDT 5.0 %	605	55[2]	±44	23	±32
Aldrin 0.25%	143	69	36	22	25
Chlordane 2.0 %	384	72[1]	19	31[2]	26
Toxaphene 0.25%	902	74	31	28[2]	22
BHC 0.2 %	915	86	15	27	20
Rotenone 2.5 %	47	90	2	13	13
Talc control	1122	91	9	13	15

[1] Significant at the one per cent level.
[2] Significant at the five per cent level.

EFFECT OF CHEMICAL AGENTS ON OVIPOSITION.—*Aëdes sollicitans* under laboratory conditions will lay sufficient eggs in 24 hours for comparative studies. The effect of irritants on oviposition was compared, therefore, with the untreated controls after 24 hours following the exposure of the females. Table 1 shows the mean number of eggs obtained per female that laid for each chemical agent and for the untreated control. For this 24-hour wet test a total of 240 females, 30 in each group, were used. The mean number of eggs per female that laid was as follows: acetone, 79; quinoline, 66; nitric acid, 58; ethyl alcohol, 54; chloroform, 51; untreated control, 48; ammonia, 45; and ether, 39. Statistical analysis, comparing treated with untreated, indicates that there is no significant difference between the number of eggs produced. It is interesting to note, however, that mosquitoes exposed to these agents were knocked down and oviposited while on their backs. Peristaltic movements of the abdomen were observed within a few seconds after the exposure. Figure 1 is a microphotograph of this phenomenon, prior to death, resulting from exposure to ammonium carbonate.

EFFECT OF INSECTICIDES ON OVIPOSITION.—The effect of various insecticides on oviposition was made under conditions similar to that used for the chemical agents, namely, a 24-hour wet run. Standard percentages of insecticides were used, as shown in table 2, and all insects were given a 60-second exposure. A total of 210 female mosquitoes was used, 30 in each group. The results are shown in table 2. No attempt was made to vary the exposure time to produce a "death stress" without mortality. Sixty to ninety per cent of the females oviposited under the influence of the various insecticides, while 80 per cent of the controls oviposited. A shorter exposure time might have given a greater percentage ovipositing, but for consistency, 60 seconds was used throughout. Also, a lower concentration of insecticide might have given a higher percentage ovipositing, but again, for consistency, the usual concentrations of insecticides were used. The mean number of eggs per female that laid was as follows: talc control, 89; benzene hexachloride, 84; toxaphene, 71; rotenone, 69; DDT, 53; chlordane, 47; and aldrin, 14. DDT, chlordane, and aldrin are significantly less than the control. The significantly fewer eggs per female in these three may be due to the concentration of the insecticide, since a lower concentration of DDT does not show less eggs per female than the controls (see table 3).

EFFECT OF VARIOUS CONCENTRATIONS OF DDT ON OVIPOSITION.—In an attempt to determine the effect of various concentrations of DDT on oviposition, a test similar to the previous ones was made with DDT in concentrations from 0.5 per cent to 5.0 per cent. The results are shown in table 3. For all concentrations used, the number of females that laid was significantly less than the control; but comparing the number of eggs laid per female, the results were as follows: talc control, 83; 0.5 per cent DDT, 83; 3.0 per cent DDT, 83; 1.0 per cent DDT, 81; 4.0 per cent DDT, 74; 2.0 per cent DDT, 52; and 5.0 per cent DDT, 45. The last two concentrations are statis-

Fig. 1.—Microphotograph showing oviposition of a female prior to death after 60 seconds' exposure to ammonium carbonate.

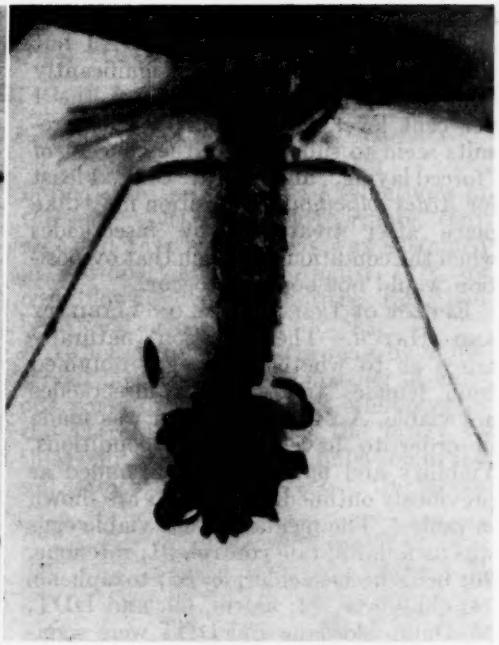

Fig. 2.—Microphotograph showing oviposition of a female prior to death after 60 seconds' exposure to 5.0% DDT.

tically less than the control at the 5 per cent level of probability, which is borderline. It appears, therefore, that the concentration of DDT affects the percentage of females that lay, and to some extent, the number of eggs laid per female. The product-moment correlation is −0.55 between concentration of DDT and percentage of females that laid; and is −0.62 between concentration of DDT and the mean number of eggs per female. These correlations are low, but do show the negative influence of increasing concentrations of DDT. However, it is important to note that oviposition does take place when the insects are subjected to the stress, and that the production of eggs is (practically) not much less than the controls for the higher concentrations, and is no less for the lower concentrations. Figure 2 is a microphotograph showing oviposition of a female prior to death, after 60 seconds exposure to 5.0 per cent DDT.

Concept of "Forced Laying."—Up to this point, the results, in general, seemed to indicate that irritants or insecticides did not markedly impair the egg-laying ability of *Aëdes sollicitans*. Observation, however, of the actual female oviposition after being knocked down gave the definite impression of what might be termed "forced laying." Obviously, under the attempted idealized 24-hour wet conditions, more eggs could not be obtained from the treated females than the controls. This assumes, of course, that 24 hours is long enought to get most of the eggs from both. If, however, "forced laying" was actually taking place, it could be demonstrated only by setting up conditions which were not conducive to normal oviposition. Since *Aëdes sollicitans* favors wet regions, and 24 hours are required for controls to produce, a run under dry conditions and at a reduced time, five hours, would not be favorable. This was done and the results are shown in table 4. The percentage of females that oviposited was as follows: talc control, 0; toxaphene, 30; aldrin, 30; chlordane, 70; rotenone, 80; 5.0 per cent DDT, 90; and benzene hexachloride, 90. All of these percentages are significantly higher statistically than that of the control, with toxaphene and aldrin at the 5 per cent level of probability, and all of the rest at the 1 per cent level. The mean number of eggs per female was as follows: talc control, 0; toxaphene, 7; aldrin, 15;

chlordane, 42; rotenone, 57; DDT, 89; and benezene hexachloride, 99. All but toxaphene and aldrin are significantly higher than the control (zero) at the 1 per cent level of probability. These results seem to substantiate the concept of "forced laying," and indicate that, at least for *Aëdes sollicitans*, oviposition may take place after treatment by insecticides when the conditions are such that oviposition would not normally occur.

EFFECT OF INSECTICIDES ON VIABILITY AND HATCH.—The question naturally arises as to whether the eggs obtained from females treated with insecticides are viable. A 24-hour wet run was made in order to have favorable conditions. Viability and hatch were determined as previously outlined. The results are shown in table 5. The mean per cent viable eggs was as follows: talc control, 91; rotenone, 90; benzene hexachloride, 86; toxaphene, 74; chlordane, 72; aldrin, 69; and DDT, 55. Only chlordane and DDT were significantly less than the control at the 1 per cent and the 5 per cent levels of probability, respectively. The per cent hatch was: talc control, 13; rotenone, 13; aldrin, 22; DDT, 23; benzene hexachloride, 27; toxaphene, 28; and chlordane, 31. Only toxaphene and chlordane were significantly higher than the control at the 5 per cent level of probability. Note that the control had the highest percentage of viable eggs, but the lowest percentage of hatch. This leads to a speculative concept of "forced hatching." Further research is needed on this point.

EFFECT OF MECHANICAL STRESS ON OVIPOSITION.—Returning to the concept that anything that kills the mosquito—short of crushing it—would cause oviposition, a "death stress" was induced by purely mechanical means, rather than chemical, in order to test the concept. When the mosquito's head was mashed, oviposition started immediately and many eggs, comparable to the number obtained with other agents, were produced, severing the head from the body with a razor blade caused oviposition to start immediately and to continue for many hours. In fact, mashing the head or severing the head did not kill the mosquito during an observed period of 16 hours overnight. Many eggs were produced during this period.

"INSECTICIDAL STRESS."—This study of oviposition under the influence of certain agents may indicate why insecticides are not always completely effective. The question naturally arises: Are as many salt marsh mosquitoes extant after a single spraying of an area as there would have been if the area had not been sprayed. Since the females of this species lay their eggs on the mud of moist marshes, and the eggs hatch when flooded by tides or rains, it appears that the answer to the above question may be "yes." *Aëdes sollicitans* favors wet regions, and oviposition under insecticidal stress could be under conditions favorable for viability and hatch. This study argues that there are three main reasons why insecticides are effective: (1) immediate kill, males and females, (2) persistent residual action affecting adults and the subsequent hatch, and (3) oviposition, under the insecticidal stress, in conditions unfavorable for viability and hatch. This latter reason may be the controlling one for various species, if further research demonstrates oviposition after exposure to insecticides.

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Feeding and Pupating Habits of the Fall Armyworm in Corn[1]

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It is commonly known that the fall armyworm, *Laphygma frugiperda* (A. and S.), occasionally ranks among the major pests of some of the forage, cereal and truck crops. Injury to corn, wheat and alfalfa is particularly important. Distribution and life history have been studied and it is therefore common knowledge that the fall armyworm is distributed generally throughout the United States east of the Rocky Mountains and in the Tropics. The insect normally passes the winter in the Gulf states in the pupal stage and in the spring the moths gradually spread northward. The fall armyworm rarely, if ever, overwinters successfully in Kansas.

In this paper, the author intends to point out two phenomena regarding larval feeding and pupation of the fall armyworm. These phenomena either have never been found reported in the literature, as is the case of larvae pupating in parts of the corn plant instead of in the soil, or have been reported occasionally by early workers and then lost in the literature, as is true of the larvae boring into the stalks of corn in a manner similar to that of the corn borers. In either case these phenomena are not commonly known by contemporary colleagues.

The fall armyworm has been studied and reported by Webster (1890), Pettit (1900), Chittenden (1901), Forbes (1920), Smith (1921), Luginbill (1950), Walkden (1950) and others. These workers report that the fall armyworm larvae commonly feed on the leaves and in the ears of corn. Boring or burrowing into the ears of corn, either from the tip or from the side, has been reported by Pettit (1900), Chittenden (1901), Forbes (1905), Hinds & Dew (1915), Luginbill (1950), Walkden (1950) and others, but with no particular reference to burrowing into the shanks. Reference to boring into the stalks of corn (Figs. 1 and 2) has not been found in the more recent literature. In Alabama, Hinds & Dew (1915) observed the worms boring into the stalks, and sometimes at the base of the ear. Furthermore, they reported that serious loss was sustained at Benton, Alabama in August, 1912, by corn blowing over because the stalks had been weakened by such attacks.

Although some workers may have observed fall armyworms pupating in various parts of the plant, all references in the literature concerning the insect in this country, refer only to pupation in the soil. Wolcott, however, reports the larvae

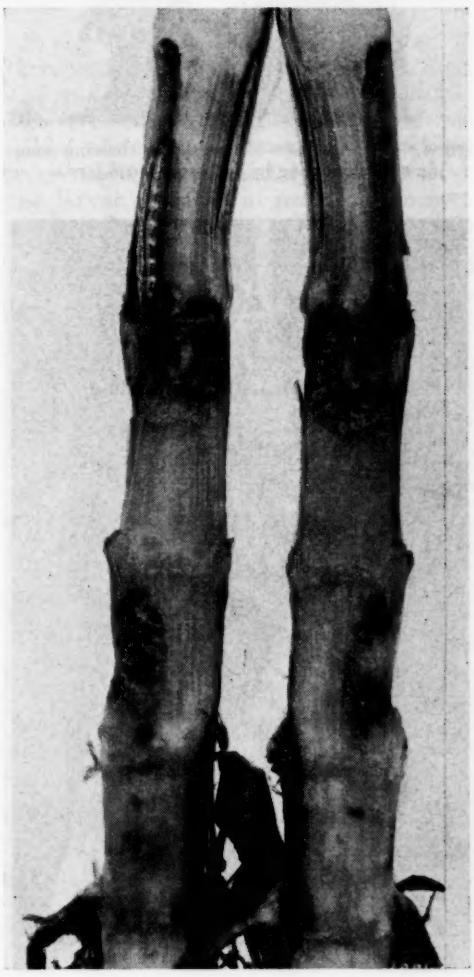

Fig. 1.—A dissected stalk of corn showing the type of injury resulting from fall armyworm larvae burrowing and tunneling in stalks.

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FIG. 2.—External view of corn stalks showing gouging and burrowing by fall armyworm larvae.

FIG. 3.—Fall armyworm injury causing weakening and breaking over of stalks.

pupating among leaves of cane or in vegetation in the Republic of Haiti.

In Kansas, the author observed that the entrance holes, and subsequent burrows up or down the inside of the stalk, were made in much the same manner as those made by some of the species of stalk borers. The type of burrowing is similar especially to that of the common stalk borer, *Papaipema nebris*, although injury from the latter usually is found earlier than that of the fall armyworm.

In some instances, the stalks had broken over (Fig. 3) due to burrowing by

FIG. 4.—Fall armyworm pupating in the tip of an ear of corn. A portion of the husk is cut away to expose the pupa.

FIG. 5.—Fall armyworm pupating in the tassel of late planted corn.

FIG. 6.—Fall armyworm pupating in the whorl of late corn. The normal procedure is to pupate in the soil.

fall armyworms. Considerable injury of the above type was observed by the author in Wabaunsee, Riley and Clay counties (Kansas) in late corn during the fall of 1951. On October 3, 1951, in a field in Riley county in which 70–75 per cent of the plants in the field showed some type of larval (armyworm) injury, approximately 3 per cent of the stalks showed burrowing by fall armyworms.

The larvae were observed making the burrows and were found feeding in the tunnels. Approximately 50 per cent of the corn in the above mentioned field had tasseled at the time of observation.

In Kansas, tunneling of corn stalks by this insect, was also noted by Gates,[3] Wilbur, and Painter[4] (unpublished), on a number of occasions. Painter observed the same type of injury by fall armyworm on corn in Guatemala in 1951.

Considerable damage by fall armyworms tunneling in the shanks of ears resulting in dropped ears also has been observed. The more usual phenomenon of boring or burrowing into ears has been reported by a number of workers.

Sorghums appear to be injured to a lesser degree than corn by the fall armyworms.

During the fall armyworm outbreak in the fall of 1951, a rather uncommon phenomenon regarding pupation was observed. Many of the larvae pupated in the ears, tassels and whorls of corn (Figs. 4, 5 and 6). No exact counts were made, but it is estimated that in two of the fields, where more intensive observations were made, approximately one fourth of the larvae pupated in parts of the corn plant and not in the soil. In this instance. the soil was not particularly hard nor dry, All references examined regarding pupation of fall armyworm in this country, refer only to pupation in the soil.

Although the habits of the fall armyworm larvae boring into corn stalks and pupating in tassels, ears, and leaves of corn may not be new, they certainly are little known and unrecognized by many colleagues. Thus it was felt that these observations should appear in the current literature.

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[4] Wilbur, D. A., and R. H. Painter, Professors of Entomology Kansas State College, Manhattan, Kansas.

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Further Studies of Orchard Acaricides

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Five species of orchard mites have become common enough in the Pacific Northwest to cause injury. They are the clover mite, *Bryobia praetiosa* Koch, the European red mite, *Metatetranychus ulmi* (Koch), the Pacific mite, *Tetranychus pacificus* McG., the two-spotted spider mite *Tetranychus bimaculatus* Harvey, and the yellow mite, *Eotetranychus carpini borealis* (Ewing), (Pritchard & Baker 1952). Newcomer & Dean (1946, 1948, 1949) reported on 10 acaricides that they tested against the European red mite and the Pacific mite from 1943 to 1948. Two of them, parathion and DMC, were effective against both species when added to DDT for controlling the codling moth, *Carpocapsa pomonella* L. Xanthone was also effective, but is no longer available. The other seven—bis(*p*-chlorophenoxy)-methane, chlordane, an amine salt of dinitro-*o*-cyclohexyl phenol, lorol-2-thiazolinyl sulfide, mineral oil emulsion, rotenone, and TEPP—were either ineffective or were effective for only a short time or when used in large quantities.

It has become standard practice among fruit growers in the Pacific Northwest to use parathion for controlling orchard mites. In 1949 and 1950 one million pounds were used in Washington alone for that purpose. Because parathion is somewhat dangerous to use and also because strains of mites resistant to it have developed (Newcomer & Dean 1952 it has been necessary to test other materials.

Methods.—All tests were made in apple orchards at Yakima, Wash., with a power sprayer and spray guns. Most of the tests were also used for evaluating the control of the codling moth and the woolly apple aphid, *Eriosoma lanigerum* (Hausm.). Thus, the spray schedule was one that a grower might expect to use during the summer for controlling apple pests. The materials used were either wettable powders or emulsifiable concentrates. Dosages are given throughout this paper in terms of pounds of the wettable powders and of pints of the emulsifiable concentrates per 100 gallons of spray.

In most of the tests in 1949 and 1950, 50 per cent DDT was used for controlling the codling moth, at 2 pounds in the first application and at 1 pound in subsequent applications. Some tests were also made with parathion at greater concentrations than are needed for controlling mites and with toxaphene and one or two other insecticides for controlling the codling moth, either throughout the season or after an initial application of DDT. In 1951. 50 per cent methoxychlor was used in the same manner as DDT in nearly all tests.

It was not found necessary to add an acaricide to the initial application. This was made just before the codling moth eggs began hatching, between May 12 and June 9, depending on the season and location of the orchards. In 1949 either two or three later applications were made, as we wished to compare these two schedules. The first application was made early in June and the last one at the end of July. In 1950 and 1951 only two later applications were made, in June and July. The interval between the first and second applications was 3 to 4 weeks, and between the second and third applications 4 to 6 weeks, the timing being primarily for codling moth control.

Plots included four to eight trees, the trees in each plot being located at random about the orchard. Ten representative leaves from each tree were used in making each count, the mites being removed from the leaves with a brushing machine. The same leaves were used for counting all species present in the orchard. Counts were made at intervals of about 10 days throughout the season, shortly before and shortly after each application and at least one count in between. Records were kept of both mites and eggs.

Although we used all these data in drawing conclusions, it would be impracticable to give them all here. We are therefore showing a single figure for each test, the average number of mites found per leaf during the last month of counting. This period was roughly August 15 to September 15, and is the time when the most serious injury usually occurs if treatments have been ineffective. These figures are shown in tables 1 to 3. It

Table 1.—Control of orchard mites with various acaricides, 1949. DDT at 2 pounds to 100 gallons alone in first application and at 1 pound with acaricide in subsequent applications unless otherwise noted.

		Orchard 1			Orchard 2		
			Average Number per Leaf			Average Number per Leaf	
Plot	Acaricide (quantity per 100 gal.)	Number of Acaricide Sprays	Pacific Mites	European Red Mites	Number of Acaricide Sprays	Clover Mites	European Red Mites
1	Parathion 15%, 0.3 lb.	3	1.5	1.7	3	0.4	0.4
2	Parathion 15%, 0.3 lb.[1]	2	1.3	1.7	2	1.0	0.2
3	Parathion 15%, 1 lb.[2]	4	0.6	1.0	3	0.1	1.2
4	Parathion 15%, 2 lb.[2]	3	0.3	0.5	2	0.1	1.2
5	DMC 25%, 1 pt.	2	0.3	1.4	2	0.2	1.7
6	DMC 25%, 1.5 pt.	2	0.2	0.4	1	0.4	1.9
7	Toxaphene 50% Em. 1 pt.	3	3.5	7.1	2	0.8	4.5
8	Toxaphene 40% WP, 1 lb.	2	9.1	5.1	2	2.5	1.5
9	Toxaphene 40% WP, 2 lb.[3]	4	6.9	4.8	2	0.7	1.9
10	Aramite 15%, 1 lb.	3	0.5	2.1	2	7.0	3.1
11	Nabam 25%, 2 qt.	3	7.3	3.3	2	6.8	4.8

[1] DDT in first application only.
[2] No DDT.

is believed that if the count during this period does not exceed six, no serious injury will be caused, although the ratio of leaves to fruit, the general vigor of the tree, and other variables may influence the occurrence of injury.

EFFECTIVENESS AGAINST DIFFERENT SPECIES OF MITES.—In 1949 (Table 1) results were obtained on the Pacific mite and the European red mite in orchard 1, and on the clover mite and the European red mite in orchard 2. Control of the two species was similar in orchard 1, but varied considerably in orchard 2.

In 1950 (Table 2) the infestation of the European red mite was very light in orchard 1, and it practically disappeared after the first application of acaricides about the middle of June. The average number of mites per leaf later was so low that no comparisons of the various treatments can be made. The figures are included in table 2 merely to show the marked reduction as compared with 1949.

Table 2.—Control of orchard mites with various acaricides, 1950. DDT at 2 pounds to 100 gallons alone in first application and at 1 pound with acaricide in subsequent applications unless otherwise noted.

			Orchard 1		Orchard 2	
			Average Number per Leaf		Average Number per Leaf	
Plot	Acaricide (quantity per 100 gal.)	Number of Acaricide Sprays	Pacific Mites	European Red Mites	Clover Mites	European Red Mites
1	Parathion 15%, 0.5 lb.	2	3.0	0	0.4	8.1
2	Parathion 15%, 2 lb.[1]	2	0.7	0	0	0.5
3	Malathon 48%, 0.5 pt.	2[3]	0.8	0.5	0	0.8
4	Malathon 48%, 1 pt.	2	0.1	0	0	0.2
5	EPN 27%, 0.5 lb.	2	3.8	0	0.7	0.2
6	DMV 25%, 1 pt.	2	0.2	0	0	0.5
7	DMC 25%, 1.5 pt.	1	0.3	0.3	0.1	2.1
8	Toxaphene 50% Em. 2.5 pt.[1]	2	4.1	0.2	0.3	5.9
9	Toxaphene 40% WP, 3 lb.[2]	3	3.7	0.2	0.3	5.1
10	Aramite 15%, 2 lb.	2	0.2	0	0.5	0.2
11	*p*-Chlorophenyl *p*-chlorobenzenesulfonate 50%, 1 lb.	2	3.6	0	0.3	0.2
12	R-242 50%, 2 lb.	2	0.6	0	0.1	0.8

[1] DDT in first application only.
[2] No DDT.
[3] In last application only in orchard 2.

Table 3.—Control of orchard mites with various acaricides, 1951. DDT or methoxychlor at 2 pounds to 100 gallons alone in first application; at 1 pound with acaricide in subsequent applications unless otherwise noted.

Plot	Acaricide (quantity per 100 gal.)	Number of Acaricide Sprays	Orchard 1	Orchard 2			Orchard 3
			Average Number of Pacific Mites per Leaf	Average Number per Leaf			Average Number of Yellow Mites per Leaf
				2-Spotted Mites	Clover Mites	European Red Mites	
			DDT, 50% WP				
1	Parathion 15%, 0.75 lb.	2	5.5	0.2	0.1	0.6	4.4
2	Parathion 15%, 2 lb.[1]	2	1.8	0.1	0	0.1	2.5
3	Parathion 15%, 2 lb.[2]	1	5.8	0.2	0	0.2	—
			Methoxylchor, 50% WP				
4	Malathon 25% WP, 1 lb.	2	3.7	0	0	1.0	1.9
5	Malathon 25% WP, 2 lb.[3]	2	2.2	0.1	0	0.3	2.1
6	Malathon 50% Em. 0.5 pt.	2	0.5	0.1	0	0.1	2.0
7	EPN 27%, 0.5 lb.	2	0.7	0.1	0	0	1.4
8	EPN 27%, 0.75 lb.	2	0.7	0.1	0.1	0.1	1.1
9	Metacide 33%, 1 pt.	2	4.7	0.1	0.6	0.6	3.0
10	DMC 25%, 1.5 pt.	1	1.2	0	0.1	0.3	2.0
11	Aramite 15%, 0.5 pt.	2	5.1	0.1	2.5	0.1	1.9
12	Aramite 15%, 0.75 pt.	2	2.1	0.1	1.7	0.3	1.8
13	*p*-Chlorophenyl *p*-chlorobenzenesulfonate 50%, 1 lb.	2	9.3	0	0	0	0.6
14	*p*-Chlorophenyl *p*-chlorobenzenesulfonate 50%, 1.5 lb.	2	12.7	0.1	0	0	1.2
15	R-242 40%, 2 lb.	2	15.7	0.1	0.1	0.1	2.7
16	R-242 40%, 3 lb.	2	13.5	0.1	0	0	2.3
17	CS-708 25%, 2 pt.[3]	2	89.5	0.3	0.3	0.8	8.2

[1] DDT in first application only.
[2] DDT in first and third applications.
[3] Methoxychlor in first application only.

No reason for this reduction was evident. Again control of the two species in orchard 2 was not always the same with any particular acaricide.

In 1951 (Table 3) no counts of the European red mite were made in orchard 1, as the infestation was again extremely low. Control of the Pacific mite was not so good as it had been, indicating the possible development of resistance. In parts of orchard 2 a heavy infestation of the two-spotted spider mite had developed late in 1950, as many as 130 mites per leaf being found by the middle of September in a plot that had been sprayed twice with 0.5 pound of 15 per cent parathion. This species was therefore included in the counts in 1951, but although the population was about 6 or 8 per leaf shortly before the first application of acaricide, it did not increase as it had in 1950 and remained at a low point for the rest of the season. In 1951 tests on the yellow mite were also made in a third orchard (Table 3).

RESULTS WITH DIFFERENT ACARICIDES. —*Parathion* (15 per cent) was used throughout these tests for comparison with the other acaricides. In 1949 it gave good control at 0.3 pound, even with only two applications (Table 1, Plot 2). At greater concentrations, of course, control was excellent (Plots 3 and 4). In 1950 it was used at 0.5 pound, and similar control was obtained, except that a rather heavy infestation, averaging 8 mites per leaf, built up late in the season in orchard 2 (Table 2, Plot 1). In 1951 the concentration was increased to 0.75 pound and control was very good, except of the Pacific mite in orchard 1 (Table 3, Plot 1). Here also a single application at 2 pounds, made on June 12, allowed a heavy infestation to build up by mid-August (Plot

Table 4.—Average number of orchard mites per leaf found after treatment with systemic acaricides, 1951.

Acaricide (1 pt. per 100 gal.)	2-Spotted Mites	Clover Mites	European Red Mites
Schradan 50%	0.9	0	0.2
Systox	0	0	0
Check (untreated)	0.5	1.5	2.0

3). Control of the yellow mite was not especially good (Table 3, Plots 1 and 2). *Malathon* was available in 1950 in the form of a 48 per cent emulsifiable concentrate, which gave excellent control of the three species on which it was tested, even at 0.5 pint (Table 2, Plots 3 and 4). In 1951 a 50 per cent emulsifiable concentrate was used at 0.5 pint and a 25 per cent wettable powder at 1 and 2 pounds, the last concentration primarily for controlling the codling moth. Again the emulsion gave excellent control of the same species and also of the two-spotted spider mite (Table 3, Plot 6). Control with the wettable-powder suspension was also excellent, except against the Pacific mite, where it was only fair (Plots 4 and 5). Control of the yellow mite was perhaps a little better than with parathion.

EPN, at 0.5 pound of a 27 per cent wettable powder, gave excellent control of all species except the Pacific mite in 1950 (Table 2, Plot 5), and the yellow mite in 1951 (Table 3, Plots 7 and 8). However, control of this mite with EPN was better than with parathion.

Metacide, tested only in 1951 at 1 pint of a 33 per cent emulsifiable concentrate, controlled the Pacific and yellow mites rather poorly, but gave very good control of the other species (Table 3, Plot 9).

Toxaphene was tested in 1949 and 1950 in a 50 per cent emulsifiable concentrate and a 40 per cent wettable powder. It controlled the clover mite very well, but even when used at 2.5 pints or at 3 pounds it gave poor control of the Pacific mite and the European red mite (Table 1, Plots 7, 8 and 9; Table 2, Plots 8 and 9), even shortly after application.

DMC was the most effective and long-lasting nonsystemic acaricide tested. Two applications at 1 pint of a 25 per cent emulsifiable concentrate in 1949 and 1950 gave excellent control of all species, although the European red mite tended to build up a little faster than the others (Table 1, Plot 5; Table 2, Plot 6). At 1.5 pints a single application in June controlled all species, including the yellow mite, very well for the rest of the season (Table 1, Plot 6; Table 2, Plot 7; Table 3, Plot 10).

Aramite in the form of a 15 per cent wettable powder was tested in 1949 and 1950. Although control of the Pacific mite was very good in 1949 when it was used at 1 pound, neither the clover mite nor the European red mite was controlled well (Table 1, Plot 10). The concentration was therefore increased to 2 pounds in 1950, and excellent control of all three species resulted (Table 2, Plot 10). In 1951 a 15 per cent emulsifiable concentrate was used. At 0.5 and 0.75 pint this material gave excellent control of the two-spotted spider mite and the European red mite, but only fair control of the Pacific mite and the clover mite (Table 3, Plots 11 and 12). Control of the yellow mite was fairly good. It is probable that at a greater concentration, as indicated in 1950, satisfactory control of all species would be obtained.

p-Chlorophenyl p-chlorobenzenesulfonate (Ovotran), as a 50 per cent wettable powder at 1 pound, gave excellent control of the two-spotted spider mite, the clover mite, and the European red mite, but poor control of the Pacific mite (Table 2, Plot 11; Table 3, Plot 13), even at 1.5 pounds. Control of the yellow mite, on the other hand, was good.

R-242 (40 or 50 per cent), at 2 and 3 pounds, controlled the various species about the same as did *p*-chlorophenyl *p*-chlorobenzenesulfonate, except that it did not control the yellow mite very well and controlled the Pacific mite poorly in 1951. A notable absence of predacious mites (*Typhlodromus* sp.) in these plots indicated that R-242 may be particularly toxic to these predators (Table 2, Plot 12; Table 3, Plots 15 and 16).

CS-708, tested only in 1951, controlled the two-spotted spider mite, the clover mite, and the European red mite, but seemed to have no effect on the Pacific mite (Table 3, Plot 17), although used at 2 pints of a 25 per cent emulsifiable concentrate. Trees infested with this species became badly browned before harvest, and the fruit was small and poorly colored. Here again, the absence of *Typhlodromus* probably had something to do with the great increase in the Pacific mites. Control of the yellow mite was also very poor.

RESULTS WITH SYSTEMIC ACARICIDES.—In 1951 two systemic acaricides, schradan and Systox, were tested in orchard 2 on some young trees that had moderate infestations of three species of orchard mites (Table 4). A single application was made on June 28, and mites were counted

at 10-day intervals until the middle of September. Although the infestation in the untreated check trees was not very heavy, Systox was effective longer than schradan, and a single application controlled the mites throughout the season. All the two-spotted spider mites and the European red mites were dead within a week after the spraying with Systox, but all the clover mites were not dead until after 3 weeks. No live mites were found on these trees after that. Schradan also killed all the European red mites within a week, but it took 2 weeks to kill all the two-spotted spider mites and 3 weeks to kill all the clover mites. However, within a month European red mites began appearing again, and in less than 2 months the other two species reappeared.

SUMMARY.—Acaricides were tested against five species of orchard mites on apple trees at Yakima, Wash., in 1949, 1950, and 1951. It required 0.75 pound of 15 per cent parathion per 100 gallons to control the two-spotted spider mite, the clover mite, and the European red mite satisfactorily, but this amount was hardly enough to control the Pacific mite, and even 2 pounds was insufficient for effective control of the yellow mite. Malathon controlled all species effectively except the yellow mite when 0.5 pint of a 50 per cent emulsifiable concentrate or 1 pound of a 25 per cent wettable powder to 100 gallons was used. EPN at 0.5 pound of a 27 per cent wettable powder gave excellent control of all species except the yellow mite. Metacide (33 per cent emulsifiable concentrate) at 1 pint per 100 gallons controlled the two-spotted spider mite, the clover mite, and the European red mite effectively, but the Pacific mite and the yellow mite rather poorly.

Toxaphene had some acaricidal value, particularly against the clover mite, but was ineffective in comparison with the other materials tested. DMC (25 per cent emulsifiable concentrate) had a longer residual effect than any nonsystemic acaricide tested, and 1.5 pints to 100 gallons used in June will ordinarily control all species, including the yellow mite, for the season.

Aramite had a somewhat selective effect. One pound of the 15 per cent wettable powder controlled the Pacific mite, but 2 pounds was required for the clover and European red mites. Half a pint of 15 per cent emulsifiable concentrate gave excellent control of the two-spotted and European red mites, but only fair control of the Pacific, clover, and yellow mites.

p-Chlorophenyl *p*-chlorobenzenesulfonate was also selective; it controlled the Pacific mite poorly even at 1.5 pounds of 50 per cent wettable powder to 100 gallons, although very good control of the other species resulted from the use of 1 pound. R-242 (40 or 50 per cent) at 2 and 3 pounds to 100 gallons gave similar results, except that it did not control the yellow mite as well as *p*-chlorophenyl *p*-chlorobenzenesulfonate did. CS-708 although used at 2 pints of a 25 per cent emulsifiable concentrate was ineffective against the Pacific and yellow mites, but quite effective against the other species.

Of two systemic acaricides applied to the foliage as sprays, Systox had a longer residual effect than schradan, although both were very effective against the two-spotted, clover, and European red mites.

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Effectiveness of Certain Insecticides Against DDT-Resistant Body Lice in Korea[1]

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The failure of DDT to control the body louse, *Pediculus humanus corporis* Deg., in Korea was perhaps first noted in December 1950, and similar observations were made during the following months. The possibility that the failures were caused by such factors as a poor quality of DDT or improper dusting procedures was investigated and rejected. Various samples of technical DDT were examined at the Orlando, Fla., laboratory of the Bureau of Entomology and Plant Quarantine and found to be up to standard in DDT content and in effectiveness against mosquito larvae and lice of a laboratory strain. Reworking the powders to improve their physical properties did not improve their effectiveness. Meanwhile, studies were conducted by Hurlbut *et al.* (1952) on the susceptibility of Korean lice to DDT under controlled conditions, and by May 1951 sufficient data had been accumulated to show that the lice were definitely resistant to DDT.

Early in June 1951, at the request of the Army Committee on Insect and Rodent Control, the writer went to the Far East to investigate the DDT-resistant louse problem. The resistance of lice to DDT was confirmed, and laboratory tests with a number of alternate materials and formulations were initiated. Subsequently, practical field tests were made with certain approved insecticide formulations to aid in the selection of a new or improved louse powder. The results of these investigations are reported herein.

LABORATORY TESTS.—*Materials and methods.*—The greatest emphasis was placed on tests with pyrethrum and allethrin, alone and in combination with different synergists and antioxidants, because of their known safety to man and effectiveness against lice. Tests were also run with lindane, toxaphene, and certain other chlorinated hydrocarbons. Although a number of them are considerably more toxic to body lice than pyrethrum, their safety for use in louse powders had not been fully established. The chemicals used in these tests were known to be pure, and the various formulations tested were freshly prepared.

A modification of the procedures described by Bushland *et al.* (1944) and Eddy & Carson (1946) was used to test the materials as cloth impregnants. The materials were dissolved in acetone at the desired concentration, and 0.7 ml. of the solution was pippetted onto circular cloth patches 1.5 inches in diameter. The treated patches were suspended on pins and allowed to dry for about an hour, after which each pad was placed in a 50-ml. beaker and 20 adult lice were introduced. The beakers were held in an improvised incubator at approximately 30° C., although temperatures reached a high of 33° and a low of 19°. The relative humidity was not determined, but water was kept in the incubator constantly. Knockdown and mortality of the lice were recorded after 24 hours' continuous contact with the treated cloth.

Insecticide powders were tested on balbriggan cloth patches 4.9 inches square. One-half gram of powder was spread over each cloth with a spatula and rubbed in lightly with the fingers. The treated cloths were placed on boards slightly larger than the cloths to facilitate handling. Wide-mouthed metal jar rings (without the disk tops), held in position with rubber bands, were used to confine the lice on the treated cloths. Practically all the powders contained pyrophyllite as the diluent, with 3 per cent of diatomaceous earth[3] as the conditioner. The treated cloths were aged indoors in a well-ventilated building.

All body lice used in the tests were collected on Koje-do Island, mostly from prisoners of war who had been dusted with DDT from time to time over a period of 6 to 9 months. A few tests were run with lice taken from civilians and from prisoners who had been captured about 2 months

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[3] Celite No. 209.

previously. The samples tested included lice from Chinese and North and South Korean prisoners of war. The lice from all these groups appeared to be equally resistant to DDT. Representative specimens were examined by C. F. W. Muesebeck and found to be *Pediculus humanus corporis* Deg. Twenty adult lice were used in each test unless noted otherwise. An attempt was made to use an equal number of males and females in each test, but because of the preponderance of females in the collections, this was not always possible.

Tests of various insecticides as cloth impregnants.—All the insecticides available were evaluated as cloth impregnants at several concentrations, by the beaker test method. Lice from several different groups of persons were used, but since all appeared to be about equally resistant to DDT, no distinction was made with respect to the source of the test insects. Results of these tests are given in table 1.

Dieldrin and aldrin were the most effective materials tested, both causing complete kill of lice in 24 hours at the low concentration of 0.001 per cent. Chlordane gave similar results at a concentration of 0.005 per cent. These materials were tested principally to obtain comparative data on the resistance of Korean lice to various insecticides, as all are considered too toxic for use on humans.

Lindane was highly effective at a concentration of 0.0025 per cent, and completely effective at 0.005 per cent. A concentration of 0.001 per cent caused 80 per cent mortality in 24 hours, whereas against normal lice in the Orlando laboratory colony (Eddy & Bushland 1948) this concentration caused 57 per cent mortality. It was concluded, therefore, that the Korean lice were not resistant to lindane. This material is not equal to DDT or several other chlorinated hydrocarbon insecticides in residual toxicity to normal lice, and it is also thought to be more toxic to human beings than DDT. However, it may be safe to use at the low concentrations required to give effective immediate control of louse infestations. In fact, powders containing 1.5 per cent of the gamma isomer of benzene hexachloride are reported to be in use in Japan, but no information on the toxic effects of its use has been obtained.

Toxaphene caused complete kill of DDT-resistant lice in 24 hours at a concentration of 0.05 per cent, but caused only 62 per cent kill at 0.005 per cent. It was somewhat slower in action than any of the other effective materials. Previous tests in the U. S. by Eddy & Bushland (1948) showed toxaphene to be slightly more effective than DDT against normal lice. Their results and those obtained in the present tests are closely comparable, indicating that the Korean lice are not resistant to this material.

The pyrethrins and allethrin at 0.1 per cent caused 100 per cent mortality of lice in 24 hours. Both caused complete knockdown at a concentration of 0.05 per cent, but the pyrethrins did not give complete mortality in 24 hours. At a concentration of 0.025 per cent (not shown in table 1) neither material caused complete knockdown or kill in 24 hours. In recent tests with the nonresistant strain of lice at the

Table 1.—Per cent of body lice dead or moribund after 24 hours' exposure to indicated concentration of insecticide.[1] Average of 2 to 9 replications of 20 lice each.

	Per Cent Insecticide									
	1.0	0.5	0.1	0.05	0.01	0.005	0.0025	0.001	0.0005	0.0001
DDT	17									
Methoxychlor	20									
Q-137	80									
TDE	100	97	60							
Allethrin			100	100	62					
Pyrethrins			100	100	65					
Toxaphene				100	88	62				
Chlordane					100	96	90	48		
Lindane						100	95	80		
Aldrin							100	100	80	60
Dieldrin							100	100	90	40

[1] On untreated pads the dead and moribund lice averaged 19 per cent.

Orlando laboratory, a concentration of 0.05 per cent of either material generally caused complete knock-down but rather low mortalities in 24 hours. It therefore appears that there is little difference in the susceptibility of normal and DDT-resistant Korean strains of body lice to allethrin and pyrethrum.

TDE and Q-137 were effective only at the highest concentration of 1.0 per cent. Methoxychlor was virtually nontoxic at this concentration. These materials had show low toxicity in previous tests against normal lice in the U. S. but were tested because of their low order of toxicity to man and because all are chemically related to DDT.

DDT at 1.0 per cent caused no greater mortality of lice than occurred in the untreated controls, and at 5 per cent (not shown in table) gave only slightly higher kill. This material, however, showed some toxicity to newly hatched nymphs. In one experiment 40 lice (10 nymphs of each stage and 10 adults) lived for 2 weeks when fed twice daily on a piece of woolen cloth impregnated with 1 per cent DDT. However, the nymphs hatching from the eggs failed to reach the second instar. For this reason it seems that some reduction of lice might result from impregnation of clothing with DDT. To determine this, observations over a period of 3 or 4 weeks would be needed. However, any material requiring 2 weeks to kill all the lice would normally not be recommended for louse control.

Tests with powders containing pyrethrum and allethrin.—Two series of tests were made with pyrethrum and allethrin. In the first series seven powders in various combinations, including one with DDT, were selected for testing in Korea because of their effectiveness in recent experiments against normal lice at the Orlando laboratory. These powders were studied from the standpoints of rapidity of knock-down and duration of residual effectiveness. The DDT-pyrethrum formula (No. 1) was a commercial preparation, but the others (Nos. 2 to 7) were laboratory preparations. The ratio of synergist to pyrethrins in these powders was 5 to 1 rather than the usual 10 to 1. The reduction in the amount of liquid synergist improved the dusting quality of the powders but reduced their effectiveness slightly, judging from the results obtained in subsequent tests with similar powders containing the usual 10-to-1 ratio of synergist and pyrethrins. The formulation of each powder and the results obtained are presented in table 2.

The formulation containing DDT and pyrethrins (No. 1) appeared to be slightly slower in causing knock-down of lice than a comparable formulation without DDT (No. 2). The knock-down with No. 2 was, in turn, slightly slower than that with No. 3, a comparable formulation with sulfoxide as the synergist instead of piperonyl butoxide.

Powders containing allethrin in addition to the pyrethrins gave a faster knock-down than powders containing only the pyrethrins. There were practically no differences in the formulations containing sulfoxide as the synergist in place of piperonyl butoxide or in those containing *Antioxidant No. 2246* in place of *Phenol S* as the antioxidant. In general, all the powders were somewhat slower in action against Korean lice than they had been in previous tests against laboratory colony lice.

In residual effectiveness Nos. 2 and 3 were distinctly less effective than Nos. 4 to 7, containing allethrin in addition to the pyrethrins.

Formulations containing sulfoxide as the synergist (Nos. 5 and 7) were superior to those containing piperonyl butoxide (Nos. 4 and 6). *Phenol S* was superior to *Antioxidant No. 2246* as an antioxidant in combination with piperonyl butoxide, but the two were about equal with sulfoxide.

The second series of tests was run with seven commercially prepared powders containing allethrin and pyrethrum in different combinations, including one with *Lauseto neu* (chloromethyl *p*-chlorophenyl sulfone). All these powders contained twice as much synergist as those in the previous series, and all were effective in knock-down tests as fresh treatments. Formulations of these powders and results of tests on residual effectiveness are shown in table 3. No. 14 caused 100 per cent knock-down in 45 minutes and all other preparations in 60 minutes.

The powder with the longest residual action (No. 14) contained pyrethrum, allethrin, and *Lauseto neu*. The three powders (Nos. 8, 9, and 10) that contained pyrethrum and 2,4-dinitroanisole were effective longer than the two (Nos. 11 and

Table 2.—Knock-down and kill of body lice exposed 24 hours to various powder formulations of pyrethrum and allethrin (average of 2 tests).

No.	Formulation	Per Cent Knock-down After—		Per Cent Dead or Moribund After—			
		1 Hour	3 Hours	1 Day	7 Days	9 Days	13 Days
1	Pyrethrins 0.2% *Phenol S* .25% Piperonyl butoxide 1.0% *Celite No. 209* 3.0% DDT 10.0% Pyrophyllite q.s. 100%	50	75	100	—	—	—
2	Same as No. 1 with DDT omitted	60	85	100	70	—	—
3	Same as No. 2 with sulfoxide substituted for piperonyl butoxide	75	95	100	55	—	—
4	Pyrethrins 0.2% Allethrin .2% *Phenol S* .25% Piperonyl butoxide 1.0% *Celite No. 209* 3.0% Pyrophyllite q.s. 100%	90	100	100	100	95	70
5	Same as No. 4 with sulfoxide substituted for piperonyl butoxide	95	100	100	100	90	85
6	Same as No. 4 with *Antioxidant 2246*[1] substituted for *Phenol S*	85	100	100	90	90	30
7	Same as No. 5 with *Antioxidant 2246*[1] substituted for *Phenol S*	90	100	100	100	90	85
	Control: Untreated	—	—	—	5	5	0
	Pyrophyllite alone	—	—	—	30	20	10

[1] 2,2'-Methylenebis(6-*tert*-butyl-*p*-cresol).

12) without 2,4-dinitroanisole but with allethrin added. The least effective powder (No. 13) was the one with the least pyrethrum and the most allethrin.

In the group of powders containing pyrethrum and 2,4-dinitroanisole, piperonyl butoxide and sulfoxide were approximately equal, and *n*-propyl isome was slightly less effective; whereas in the group containing pyrethrum and allethrin piperonyl butoxide was slightly more effective than sulfoxide.

Tests with lindane and toxaphene powders.—Lindane was tested for knock-down and residual effectiveness at a wide range of concentrations in pyrophyllite. The results are given in table 4.

A lindane concentration of 0.5 per cent gave complete knock-down of lice in 30 minutes, and concentrations of 0.1 and 0.25 per cent gave similar results in 1 hour. These results are closely comparable to those obtained in previous tests with normal lice. The 1 per cent lindane powder was completely effective for 9 but not for 13 days. Since louse eggs require 8 to 10 days to hatch, lindane at concentrations of less than 1 per cent might not eradicate an infestation in one treatment. Under practical conditions two or three treatments with the 1 per cent powder might be required.

No detailed laboratory tests were conducted with toxaphene, but one series was run to determine the residual effectiveness of 10 per cent of toxaphene in pyrophyllite. Patches treated with this powder were completely effective against resistant strains of lice after 3 weeks' aging. Similar results have been obtained in tests against normal lice.

Tests with DDT powders.—Tests were conducted with DDT powders at several concentrations. Most of the powders were prepared from a sample of pure DDT obtained from the Orlando laboratory, but a freshly prepared commercial DDT powder was also used. The lice used in these tests were taken from both North and South Korean prisoners of war. Typical knock-down and mortality data obtained 24 hours after treatment with 10 per cent of DDT in pyrophyllite are shown in table 2.

Table 3.—Kill of body lice exposed 24 hours to several commercially prepared louse powders containing pyrethrum and allethrin. Average of 2 tests.

No.	Formulation		Per Cent Dead or Moribund After—				
			8 Days	10 Days	12 Days	14 Days	16 Days
8	Pyrethrins (from 20% extract) Piperonyl butoxide 2,4-Dinitroanisole *Phenol S* *Celite No. 209* Pyrophyllite q.s. 100%	0.2% 2.0% 2.0% .1% 3.0%	100	100	95	95	85
9	Same as No. 8 except that sulfoxide is substituted for piperonyl butoxide		100	98	98	90	70
10	Same as No. 8 except that n-propyl isome is substituted for piperonyl butoxide		95	88	85	85	—
11	Pyrethrins Allethrin Piperonyl butoxide *Phenol S* *Celite No. 209* Pyrophyllite q.s. 100%	0.2% .2% 2.0% .1% 3.0%	100	98	83	65	—
12	Same as No. 11 except that sulfoxide is substituted for piperonyl butoxide		98	100	73	10	-
13	Pyrethrins Allethrin Sulfoxide *Phenol S* *Celite No. 209* Pyrophyllite q.s. 100%	0.1% .4% 2.0% .1% 3.0%	100	88	55	—	—
14	Pyrethrins Allethrin Sulfoxide *Antioxidant No. 2246* *Lauseto neu* *Celite No. 209* Pyrophyllite q.s. 100%	0.2% .3% 2.0% .25% 5.0% 3.0%	100	100	98	98	100
	Pyrophyllite (control)		20	18	13	13	15

	Per Cent Knock-down	*Per Cent Mortality*
DDT:		
Laboratory prepared	30	25
Commercial	35	30
Control:		
Pyrophyllite alone	40	40
Untreated	20	20

The mortality with pyrophyllite was higher than normal in this test.

Powders containing 10 per cent of DDT in pyrophyllite and in talc caused very low mortality of lice. The kill was usually little higher than on talc and pyrophyllite controls. Previous experience has shown that these and other diluents may cause some mortality of lice depending upon temperature, relative humidity, particle size or abrasiveness of the diluent, and condition of the lice.

In tests against normal laboratory-colony lice at Orlando, powders containing only 0.1 per cent of DDT usually give 100 per cent kill in 24 hours. Since 10 per cent DDT powders proved only slightly toxic to the Korean lice, it is evident that these lice are at least 100 times more resistant to DDT than normal lice.

Tests against head lice.—In the course of collecting body lice from Chinese and North Korean refugees, collections were also made of head lice, *Pediculus humanus humanus* L., for laboratory tests. Two lots of 20 lice were exposed on cloth impregnated with 1 per cent DDT. In 3 hours 80 to 90 per cent of the lice were knocked down and all exhibited typical DDT tremors prior to death. Complete mortality occurred in 6 to 12 hours. The control showed only 10 per cent mortality.

Body lice taken from the same individuals as the head lice were highly resistant to DDT.

Table 4.—Knock-down and mortality of body lice exposed 24 hours to various concentrations of lindane in pyrophyllite.

Per Cent of Lindane	Per Cent Knock-Down After—				Per Cent Mortality After—		
	30 Min.	1 Hr.	3 Hrs.	24 Hrs.	7 Days	9 Days	13 Days
1.0	100	—	—	—	100	100	80
0.5	100	—	—	—	95	85	50
.25	75	100	—	—	80	80	20
.1	75	95	100	—	45	—	—
.01	0	0	0	95	20	—	—
.001	0	0	0	75	—	—	—
Controls:							
Pyrophyllite alone	0	0	0	20	40	40	10
Untreated cloth	—	—	—	—	5	5	0

FIELD STUDIES.—The prevalence of lice among civilians and Asiatic military personnel in Korea afforded an excellent opportunity for the practical evaluation of louse powders. Therefore, fairly large-scale tests were conducted with several approved powders that were available in quantity.

DDT-pyrethrum powder.—A powder combining 10 per cent of DDT and 0.2 per cent of pyrethrins (No. 1, table 2) was developed to meet the need of a general-purpose dusting powder that would give a quick knock-down of lice, fleas, and other insects and still provide long residual toxicity. When this formulation was first suggested, DDT-resistant lice in Korea had not been reported, but this problem offered an opportunity to determine whether the formulation would be more effective than DDT alone. Subsequent laboratory tests indicated that this powder had no advantage over a regular pyrethrum powder without DDT, but the material was nevertheless included in the field tests for comparative purposes.

The DDT-pyrethrum powder was applied to 120 infested persons, 60 by power duster and 60 by hand with a standard 2-ounce shaker-type can. Slightly less than 2 ounces per person was applied by power duster and slightly more than 2 ounces by hand. Each group was housed in a separate tent. The powder was applied to the clothing, but blankets and mats were not treated, nor was any insecticide dusted inside the tents. Two treatments, 9 days apart, were made. An attempt was made to keep the treated persons from contact with others and from washing their clothing, but actually little control over their activities was obtained.

Counts of lice on the inner top garment, in most cases an undershirt, were made before and at intervals after treatment. Although the counts of adults and nymphs were recorded separately, the two counts are combined in the data presented below. A second treatment was applied on the ninth day shortly after counts were made.

	Power Application	*Hand Application*
Before treatment	311	471
After treatment:		
3 days	138	91
9 days	325	140
12 days	90	29

A reduction of lice was caused by both methods of application, but a distinctly greater kill resulted from the hand treatment. The difference between the two methods might in some instances mean the difference between good control and eradication of lice. The results of this test clearly indicated the ineffectiveness of DDT against Korean lice. Normally a powder containing only pyrethrum and a synergist would be expected to cause at least as great a reduction of lice as the DDT-pyrethrum powder.

Comparison of DDT-pyrethrum and two pyrethrum-allethrin powders.—Sufficient quantities of DDT-pyrethrum (No. 1, table 2) and two allethrin-pyrethrum powders (Nos. 4 and 5, table 2) were available to conduct a small-scale field test. Six infested persons were treated with each powder and housed in a separate squad tent. The powders were applied to the clothes by hand from shaker-type cans. Blankets and mats were not treated. The lice on the inner top garment (usually an undershirt) were counted, and the counts for each group of six men were combined. The results are shown in table 5. A second treatment was applied on the eighth day after counts were made.

The test was discontinued after the tenth day, as untreated louse-infested clothing was introduced. On the basis of

Table 5.—Numbers of body lice found on persons treated with DDT-pyrethrum and two allethrin-pyrethrum powders.

POWDER	BEFORE TREATMENT	AFTER 4 Days	AFTER 8 Days	AFTER 10 Days
DDT-pyrethrum (No. 1)	68	14	33	5
Allethrin-pyrethrum:				
No. 4	48	9	40	3
No. 5	47	2	10	0

general infestation at the last two examinations No. 1 appeared to be the least effective of the three powders. No. 5, appeared to be somewhat more effective than No. 4, but it is unlikely that either would have completely eradicated the infestation.

Tests of pyrethrum and allethrin louse powders.—Sufficient quantities of six additional louse powders, three containing pyrethrum and three a mixture of pyrethrum and allethrin, were available for small-scale practical tests (Table 3). These powders were tested on persons from a prison compound where the infestation ran close to 100 per cent and individual infestations were exceptionally heavy.

Most of the individuals had in their possession one fatigue suit, one suit of underwear (summer weight), one wool jacket, cap, socks, one or two wool blankets, and a raincoat or poncho, and a few individuals had overcoats. In addition, a number of miscellaneous garments were worn. Because of the variety of outer garments worn and the high percentage of lice found on the underwear, only the inner garments, usually an undershirt and shorts, were used as an index to the number of lice present and the control obtained by the treatments.

Each of the six powders was applied to a group of 50 men, and each group occupied one squad tent. The powders were applied with a power duster, an average of slightly less than 2 ounces per man. Each treatment consisted of three applications at 8-day intervals. All clothing was dusted, including socks. Raincoats, blankets, and mats were not treated, and no material was dusted inside the tents.

The persons treated were isolated in an area enclosed by a high fence, and considerable effort was made to keep the groups separated during the day. However, no such control could be maintained at night.

Before treatment the count of lice ranged from 611 to 722 for each group of 50 men (table 6). The counts after treatment are given in table 7. Three days after the first treatment all six preparations had caused a high reduction of lice. The lowest count at this time was 17 and the highest 41, less than one louse per person. Whether some of these lice had been missed by the treatment or had come from inside the tents was not known. Examinations after 7 days showed an increase in the number of lice for all treatments. This increase was due mostly to nymphs hatching from eggs not killed by the treatments.

On the tenth day, or 2 days after the second application, the counts were very low. On the fifteenth day, or 7 days after the second application, there was a slight increase of lice for five of the six powders.

On the sixteenth day, 3 days after the third treatment, the number of lice ranged from 0 to 3. Seven days later the highest count was 8 (5 were found on one person) and the lowest was 1. Only 2 to 6 per cent of the various groups was infested, as compared with 100 per cent at the beginning of the test.

These results indicated that under ideal conditions two or three applications with any of the powders might be sufficient to eradicate lice.

Table 6.—Distribution and abundance of lice found on persons before new test powders were applied.

FORMULATION No.	IN SHIRT		IN SHORTS		TOTAL	AVERAGE PER PERSON
	Adults	Nymphs	Adults	Nymphs		
8	51	216	86	298	651	13.0
9	42	253	79	276	650	13.0
10	41	263	53	283	640	12.8
11	27	246	82	337	692	13.8
12	15	288	64	355	722	14.4
13	17	228	67	299	611	12.2
Total or average	193	1,494	431	1,848	3,966	13.2

Table 7.—Numbers of lice found on 50 persons treated three times at 8-day intervals with six louse powders containing pyrethrum and allethrin.

Formulation No.	Before Treatment	After Treatment					
		3 Days	7 Days	10 Days	15 Days	19 Days	22 Days
8	651	22	41	8	20	0	4
9	650	21	78	14	14	1	8
10	640	18	44	6	42	0	3
11	692	41	54	4	8	1	2
12	722	17	94	6	32	3	1
13	611	20	69	4	14	0	2

The following factors influenced the results in these tests:

1. The washing of treated garments was observed on numerous occasions.
2. Many persons were observed shaking or beating the clothes immediately after the powders were applied.
3. Untreated or infested clothing was exchanged for treated clothing.
4. Some treated persons had contact with infested, untreated groups of persons.

SUGGESTIONS ON THE USE OF PYRETHRUM POWDERS.—Properly formulated and applied pyrethrum preparations should give good control of lice. In general, however, pyrethrum is not comparable with DDT, toxaphene, or chlordane in residual toxicity to lice or other insects.

Although lice increase in numbers during the winter months, the powders should also prove more effective in cold weather. At this time infested persons perspire less, and there is less laundering, changing, and exposure of clothing to sun and air. All these factors influence the life of the powders and no doubt affected the results obtained in the field tests reported herein.

Application of the powder.—Thoroughness of treatment cannot be overemphasized. Even a partial job of dusting with a long-lasting material such as toxaphene might prove sufficient, but pyrethrum powders must be applied more thoroughly. Besides being applied to the clothing, the powder should be applied inside the tents, to blankets and other bedding, and to garments that might be worn later.

Pyrethrum powders probably will not flow so freely as the DDT powder because of the oil in the formulation. For this reason, complete coverage may require more effort and care on the part of the dusting crews.

Interval between treatments.—A louse powder that does not kill all the eggs or last through their incubation period must be reapplied at suitable intervals. The eggs and nymphal stages of the body louse require 8 to 10 days for development. Treatments with pyrethrum powders therefore would normally be spaced about 8 to 10 days apart. The number of treatments will, of course, be determined largely by the degree of control obtained. If the lice are greatly reduced by the first few applications, eradication should be accomplished rather quickly. It is suggested, therefore, that the first four applications be made every 5 days and others every week if reinfestations persist.

COMMENTS ON RESISTANCE.—The question has been raised as to whether body lice in Korea and Japan have developed resistance to DDT. The development or resistance to DDT by house flies is well known, and it would be natural to believe that the same thing has happened to the body louse. Apparently DDT has been available in Korea, Japan, and parts of China since about 1945. It has been observed for sale in Pusan, Korea, and has been found in refugee camps on Koje-do Island, Korea.

Therefore, we cannot be sure that any particular sample of lice collected in such areas has not had previous contact with DDT. On the other hand, the level of susceptibility of the lice to DDT prior to their first contact with this insecticide is not known, nor has it been determined that they have an inheritable resistance factor permitting an increase in the level of resistance by selection. Although all samples of lice collected were found to be highly resistant to DDT, a susceptible strain might have been encountered had more collections been made.

SUMMARY.—In 1950 at the request of the Army the author undertook an investigation of the DDT-resistant louse problem and tested a number of materials and formulations in Korea. Some of the more important results of the investigations were as follows:

A high resistance to DDT by body lice, *Pediculus humanus corporis* Deg., in Korea was confirmed by studies during July and August 1951. Whether the resistance was natural or was acquired through the use of DDT is not known.

Head lice taken from Korean and Chinese refugees were susceptible to DDT, exhibiting typical DDT tremors prior to death, whereas body lice taken from the same individuals were not susceptible to DDT.

Laboratory tests indicated that body lice in Korea were about as susceptible to TDE, allethrin, pyrethrins, toxaphene, chlordane, lindane, aldrin, and dieldrin as normal laboratory-colony lice at the Orlando laboratory.

In laboratory tests on residual effectiveness, the pyrethrins-2,4-dinitroanisole formulations appeared somewhat more effective than similar formulations containing allethrin in place of 2,4-dinitroanisole.

The results obtained in laboratory tests with a powder containing 1 per cent of lindane indicated that more than one treatment would be required to eradicate lice under practical conditions. Other tests indicated that a 10 per cent toxaphene powder might have sufficient residual effect to eradicate lice in one treatment.

A DDT-pyrethrum powder caused only fair reduction of lice in two treatments in small-scale field tests. Hand applications from 2-ounce cans caused greater reductions than power applications.

Six pyrethrum and allethrin powder formulations caused good reductions of lice in field tests after one treatment and almost complete eradication after three treatments. All six formulations appeared to be equally effective.

For practical use under conditions of heavy infestations it is suggested that the first four treatments with pyrethrum powders be made every 5 days, and subsequent ones weekly if reinfestations persist. It is recommended also that bedding as well as clothing be dusted where possible.

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Spider Mites of Citrus and Texas Citrus Mite Control in the Lower Rio Grande Valley of Texas

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The various spider mites which attack citrus, in the Lower Rio Grande Valley of Texas, has been a subject given but little consideration in years past. Most citrus growers of the area refer to the common spider mite as "red spider," assuming the mite to be the citrus red mite, *Paratetranychus citri* McG., which has been the spider mite of economic importance in California and Florida according to Ebeling (1950). The citrus rust mite, *Phyllocoptruta obeivora* Ashm., has been considered the most important mite in this area with the Texas citrus mite, *Eutetranychus* (*Anychus*) *clarki* McG., being of secondary importance during late summer and early fall months except during the past few drouth years. The results of two years' observations on these two species of mites and others are herein presented as well as results of tests to control the Texas citrus and rust mites. Dust applications were emphasized since mite control is effected principally by the use of acaracide dusts in the area.

Unpublished records of the Texas Agricultural Experiment Station, Weslaco,

[1] Acknowledgment is due Dr. E. W. Baker of the Division of Insect Detection and Identification, Washington, 25, D. C. for the identification of the various spider mites and Mr. E. A. McGregor, Bureau of Entomology and Plant Quarantine, Whittier, California for making certain records available.

Acarcides furnished by the American Cyanamide Co., Dow Chemical Co., E. I. du Pont de Nemours & Co. (Inc.), Naugatuck Chemical Division of the United States Rubber Co., Niagara Chemical Co. and Stauffer Chemical Co.

Texas, referred to "red spiders" in test data over a number of years prior to 1935. H. E. Ewing, in June, 1930, identified specimens of mites submitted by S. W. Clark, Entomologist of this Station at the time, as *Paratetranychus pilosus* var. *citri* McG. McGregor (1935) described the common spider mite of this area as a new species, *Anychus clarki* McG., intermediate between *A. banksi* and *A. rusti*. Further references in the annual reports of the Station were made to Texas citrus mites. Records of the Division of Insect Detection and Identification, Washington, D. C., as well as those of Mr. E. A. McGregor and other authoritative sources show no record of *P. citri* McG., as ever having been identified from Texas, although the mite is known to occur in Louisiana. McGregor (1950) records the distribution of *A. clarki* in Costa Rica, Mexico and Texas and the food plants as citrus, croton and orange.

PHYTOPHAGOUS MITES.—*Texas citrus mites.*—This mite prefers the upper surface of the leaf. No webbing by this mite has been observed. Eggs are disk like, ranging in size from .13 to .15 mm. in diameter. They are usually laid on the sides of the mid rib and branching veins. Eggs are transparent when first laid, but before hatching the reddish to brownish outline of the mite can be seen through the egg membrane. The mites vary in color from a lemon yellow to a dark green with dark blotches on each side down the back. Sometimes these dark blotches form an H on the back. If individuals are allowed to die and dry, they tend to become reddish in color. Males have smaller bodies and longer legs than the females. After heavy feeding by the mite the leaf will take on a gray appearance. The mites prefer citrus but have been observed to transfer to other hosts when the populations increase to large numbers on citrus.

Texas citrus mites were observed to be in relatively small numbers during October, 1950, at the Weslaco Experiment Station. Heavy September rains were thought to be one of the chief causes for this reduced population. By December, 1950, mite populations had increased to an average of 65 per cent infested square inch areas of upper leaf surface. On December 7, the temperature fell to a low of 24° F. and for a period of 14 hours below 32° F. The mite population remained unchanged during the period.

No active mites or mite eggs could be found immediately following the disastrous freeze of January 29–February 3, 1951, during which the temperature dropped to a low of 18° F. and temperatures remained below 25° F. for 20 hours and below 32° F. for approximately 75 hours. Even in three groves where the trees held from 10 to 50 per cent of their green leaves, no mites could be found. Several drouth months followed the freeze. By May, 1951, the mites had reappeared in a few groves. Heavy mite populations were noted in a number of groves during late June and early July. Continuous day and night winds blew through the summer months and prevented adequate control of the mite with dusts. Most citrus growers were in doubt as to the recovery of the trees and since only a light crop could be expected, few growers used any type of acaricide.

On a visit to the Carrizo Springs-Crystal City citrus area in December, 1951, Texas citrus mites were not found. The mites were observed at this time on orange leaves at Laredo, on orchid tree leaves at Roma and on chinaberry tree leaves at Rio Grande City. In July, 1952, the mites were found in small numbers as was the predatory mite *Iphidulus finlandulus* Oudms.

Other mites.—On January 12, 1952, *Brevipalpus australis* Tuck. was taken from grapefruit leaves in the San Juan area and the record is considered a first record of its occurrence in Texas. This mite prefers the under-surface of the leaf and can usually be found next to the mid rib. Large numbers of the mites have not been observed in any one grove, but it is widely distributed throughout the valley. Movement of this mite is very slow. Fruit may be infested as well as the leaves.

Specimens of *Septanychus mexicanus* McG. were found for the first time in the U. S. A. on January 18, 1951, at Monte Alto, Texas, on lemon leaves. Later visits to the grove showed *B. australis* McG. present but no *S. mexicanus* McG. A probable identification of the mite was made in the Bayview area on May 25, 1951, on grapefruit leaves. *S. mexicanus* McG. has not been taken since the freeze and only a few individuals have been taken at any location. McGregor (1950) reported the mites to have been intercepted at the International Bridge, Laredo, Texas.

The mite, *Thyreophagus entomophagus*

Table 1.—The effect of various acaricidal sprays to the Texas citrus mite at the Texas Agricultural Experiment Station No. 15.

Acaricide	Dose[1]	Percentages of Square Inch Areas of the Upper Leaf Surface Infested with Mites								Per Cent Control[3]
		June 11		June 16		June 20		June 27[2]		
		1–14	15+	1–14	15+	1–14	15+	1–14	15+	
No Treatment		18.7	78.7	56.0	31.3	51.0	40.3	58.0	15.3	
Aramite 60 EM	.4	16.7	79.3	16.0	2.0	26.7	10.3	27.0	2.3	59.5
Sulphenone 40 WP	1.0	27.7	68.7	30.7	3.3	36.3	26.3	54.7	4.3	18.6
Sulphur WP	10.0	25.7	58.0	34.3	26.3	35.3	16.0	48.3	2.3	19.5
Ovotran 50 WP	.4	30.7	58.0	33.0	3.7	38.3	12.0	45.0	1.0	31.1
Parathion 15 WP	.225	19.3	79.7	28.3	3.0	35.7	19.0	43.6	5.3	34.3
Neotran 40 WP	.8	6.3	93.0	22.3	26.0	30.3	16.0	35.4	5.7	45.2

[1] Pounds of active ingredients per 100 gallons of water as applied on June 25, 1951.
[2] 3.72 inches rain fell on June 25th.
[3] Abbott's formula (1925) except that percentages of infested square inches are used.

Lab., was found at several locations on fruit one inch in diameter and larger as well as on old fruit which were allowed to remain on the trees. Large populations were noted, however, only on the old fruit.

PREDATORY MITES.—Clancy & Pollard (1952) reported that *Iphidulus* sp. is undoubtedly one of the most effective predators of phytophagous mites, particularly at low host densities, but that it is unable to survive the sulphur and DDT sprays presently used in commercial orchards. The most numerous and widely distributed predatory mite that might have given some reduction of Texas citrus mite populations was found to be *Iphidulus finlandicus* Oudms. Several abandoned citrus groves have been noted to have large numbers of this predatory mite where heavy Texas citrus and rust mite populations existed. The mite has also been found to be numerous around heavy chaff scale, *Parlatoria pergandii* Comstock, Glover scale, *Lepidosaphes gloverii* Pack., and California red scale, *Aonidiella aurantii* Mack., infestations where Texas citrus and rust mites were difficult to find.

A large red predatory mite, *Allotrombidium* sp., has been observed to feed on Texas citrus mite eggs, nymphs and adults. Feeding has also been observed on Glover and chaff scale. Although large populations have been noted in only a few instances, the mite has been found widely distributed and at times seemingly absent altogether from citrus.

Records have been made of the occurrence of the following predatory mites: *Tydeus* sp., *Pronenatus* sp., *Balaustium* sp., *Amblyseius* sp., *Bdella* sp., and *Typhlodromus finlandicus* Oudms. The importance of the above named mites in reducing phytophagous-mite populations in this area is indeterminate at this time.

CONTROL WORK.—*Sampling technique.*—Linen test counters were used in estimating the mite populations. Leaves were selected at random from the newest hardened-off leaves taking 50 leaves from the outer periphery of the tree, except in Experiment 1 where 10 leaves per tree were randomly selected on 10 consecutive trees. Examination of one square inch areas of the upper surface of the leaf was made and comparisons of populations were made on the basis of per cent of square inch areas infested with active mites.

Method of application.—Dusts were applied during the early morning with a power duster mounted on a trailer which was pulled by an orchard tractor. Dusts were applied to both sides of the trees. In Experiment 1, sprays were applied by a hand spray gun leading from a 30-gallon Bean sprayer operated at from 250–300 pounds pressure. Sprays were applied in Experiments 2 and 3 during late morning by hand spray guns leading from a 500 gallon sprayer with pressure regulated to 550 to 600 pounds. In all cases, trees were sprayed in quadrants and an effort was made to cover the trees and still have as little run-off as possible.

EXPERIMENTS.—*Experiment 1.*—Only one application of spray was applied in Experiment 1 as shown in table 1. Since winds did not cease to blow during the course of this experiment, sprays were used in order that better coverage might be obtained. The two year old nursery trees were from 3 to 5 feet in height and had been protected through the freeze. Each average per cent infestation repre-

Table 2.—The effect of various acaricides to the Texas citrus mite in tests conducted at mile 13.6 N and mile 5 W.

Acarides	Dose,[1] Lbs.	Date Treated	Percentages of Square Inch Areas of the Upper Leaf Surface Infested with Mites									
			12-13	1-26	3-13	4-1	5-1	5-22	6-18	7-1	7-22	Ave.[2]
Electric sulphur	1.0	12-20	8	4	18							
	1.5	3-18				15	67					
	1.5	5-7						19	55			
	1.3	6-27								31	73	26.2
Bentonite-sulphur spray[3]	9.6	12-20	10	6	27							
Sulphur-copper spray[4]	12.0	3-18				11	68					
Bentonite sulphur spray[5]	10.0	5-7						16	66			
	10.0	6-27								41	86	29.6
Electric sulphur	.9	12-20	18	4	42							
3% Aramite-inert	1.5	3-18				11	76					
	1.5	5-7						29	66			
	1.5	6-27								15	60	28.4
Red brand sulphur	1.4	12-20	10	3	39							
Bentonite-sulphur-copper[6]	.6	3-18				26	80					
	1.4	5-7						29	68			
Bentonite-sulphur[7]	1.5	6-27								47	71	32.9
10% Ovotran												
80% sulphur	1.2	12-20	24	7	61							
	.8	3-18				11	79					
	1.0	5-7						30	87			
	1.1	6-27								29	54	35.4
DN-111 (20 WP)-sulphur spray	1.25/10	12-20	19	0	41							
1% DN-sulphur	.8	3-18				13	84					
Neotran-sulphur spray	2/10	5-7						27	77			
	2/10	6-27								50	57	31.8
Electric sulphur	1.1	12-20	19	18	78							
1% Karathane-inert[8]	.7	3-18				44	92					
	.9	5-7						79	78			
	1.3	6-27								26	65	47.2

[1] Dose as pounds per tree or pounds per 100 gallons water.
[2] Seasonal average of 14 records.
[3] Fused bentonite sulphur, 30% sulphur.
[4] 72.6% sulphur, 6% copper (expressed as metallic).
[5] 15% fused bentonite sulphur, 83% sulphur.
[6] 13.5% fused bentonite sulphur, 60% sulphur, 6% copper (metallic).
[7] 15% bentonite sulphur, 84% sulphur.
[8] Dinitro capryl phenyl crotonate.

sented 300 sampled square inches of leaf surface.

Although aramite more effectively reduced Texas citrus mite populations in this experiment, no acaricidal material used was very effective during the period records were taken. Data showed that a follow-up application would be necessary to control high populations of the mite when the materials must be applied under windy, drouth conditions. The June 27 record showed the total number of mites had been reduced following the rain on June 25th, but the total number of infested square inch areas remained about the same.

Experiment 2.—Due to heavy rust mite populations, Experiment 2, as shown in table 2, was begun before certain materials were received. Every material used in the first application greatly reduced the rust mite population. Experimental plots consisted of equal numbers of 14 year old valencia orange and pink marsh grapefruit trees. The orange trees survived the freeze exceptionally well and had required very

Table 3.—The effect of various acaricides to the Texas citrus mite in tests conducted at mile 8.25 N and Baseline Road.

Acaricides	Dose,[1] Lbs.	Date Treated	Percentages of Square Inch Areas of the Upper Leaf Surface Infested with Mites									
			12-18	1-2	2-28	3-20	4-8	4-22	5-20	5-29	7-9	7-29
Bentonite-sulphur spray[2]	8	12-20	9	12	53	47	59					
Bentonite-copper-sulphur spray[3]	12	4-15						28	35	38	54	20
1% EPN-inert	1.0	12-20	33	26	80	55	60					
Bentonite-copper-sulphur[4]	1.1	4-15						27	52	60	11	12
DN-111 (20 WP)-spray	1.25	12-20	15	0	10	26	59					
1% DN-sulphur	1.59	4-15						24	68	48	9	19
10% Ovotran-80% sulphur	1.07	12-20	6	1	15	40	77					
	1.32	4-15						17	35	56	11	11
Electric sulphur	1.0	12-20	10	2	13	35	61					
Electric sulphur	1.33	4-15						31	39	50	17	6

[1] Dose as pounds per tree or pounds per 100 gallons water.
[2] Fused bentonite sulphur, 30% sulphur.
[3] 72.6% sulphur, 6% copper (expressed as metallic).
[4] 13.5% fused bentonite sulphur, 60% sulphur, 6% copper (expressed as metallic).

little pruning. Most of the grapefruit had required pruning, but had equal to greater spread than the orange trees. Infestation records were made on four orange and grapefruit trees per plot, but since no difference of Texas citrus mite infestations resulted, an average figure is given.

Extremely dry weather prevailed during the course of the experiment. Two light showers fell on April 24 and 25. Very light showers fell on June 8, 9 and 10. Immediately after the June 27 application, a 0.2 inch of rain fell followed by a 0.3 inch of rain the following day. The latter rain was the largest of any consequence.

Texas citrus mites were at low population numbers at the outset of the test, having just undergone a reduction from natural causes. Populations of mites in the south end of the grove where 1 per cent Karathane was applied were higher from the beginning as compared to the north end where Electric sulphur was applied. Dosages of 1 per cent Karathane below 1.25 pounds per tree for this size of tree is apparently too light to arrest heavy infestations of Texas citrus mites, as compared to the other materials. DN-111-sulphur spray was particularly effective in reducing mite infestations during the winter. Three per cent Aramite-inert dust was as effective as the other materials but like those other materials a follow-up application would be necessary if heavy mite populations were to be controlled during spring months under drouth conditions. Ten per cent Ovotran-80 per cent sulphur dust gave good initial control but populations developed again after one month. Low dosage probably accounts for the poorer control with the bentonite-sulphur-copper dust mixture. Other materials, as applied, gave no better control of the Texas citrus mite than sulphur dust.

Factors other than the mere application of acaricides should be given due consideration. Rain and wind are no doubt important considerations and rain probably was the principal reason for lack of control following the June 26 application. While making rust mite records on June 28, predatory mites were found to be increasing in the Aramite and Karathane plots, the only plots where rust mite counts were made.

Rust mite counts were made in the 3 per cent Aramite and 1 per cent Karathane plots averaging 32 and 22 per cent infested square inch areas of bottom leaf surfaces, respectively on March 13. Infestations were 4 and 6 per cent on April 1, 4 and 3 per cent on April 24, 25 and 31 per cent on June 18 and 7 and 7 per cent

on July 22. Rust mite damaged fruit was particularly noticeable on grapefruit in the 1 per cent Karathane treated plots. In the 3 per cent Aramite plots, rust mites were in very low numbers but were increasing particularly on the grapefruit at the last count. Part of this lack of control might be attributable to the position of the grapefruit trees on the windward side of the grove and to the difficulty of completely covering the grapefruit trees as compared to the orange trees. Rust mites were of no concern in the other plots treated with materials containing sulphur.

Experiment 3.—Test trees for Experiment 3, as shown in table 3, were 20 year old white Marsh grapefruit trees. Rust mites were in particularly high numbers before the first application of acaricides in December. A few days before the March 20 record, an airplane made one swath across all treatments with sulphur dust by mistake. A very late bloom occurred as may be noted from the post-bloom application on April 15. Light showers fell on April 18. Heavier rains fell during late May and again in June. Since no Texas citrus mite eggs were observed at the July 9 record and since spider mite infested leaf areas were light on July 29 and rust mite populations were increasing, the grove was turned back to the grower for rust mite control.

It is particularly interesting to note that DN-111 was found to be very toxic to the Texas citrus mite, but had reduced rust mites only 41 per cent on January 2 according to upper leaf surface records made at the same time that spider mite records were taken. One per cent EPN-inert gave poor control of the Texas citrus mite and reduced the number of rust mite infested square inch areas of upper leaf surface only 29 per cent. Ten per cent ovotran-80 per cent sulphur dust gave good initial control but infestations built back up in 30 to 60 days.

Summary.—The Texas citrus mite, *Eutetranychus clarki* McG., has been discussed as to its relative abundance during the past two years and through two freezes. The doubt has been raised as to whether or not the citrus red mite, *Paratetranychus citri* McG., has ever been recorded from Texas. *Brevipalpus australis* Tuck. has been found to be widely distributed but of no economic importance at this time. Several species of predatory mites have been found, some of which might play important roles in the natural reduction of Texas citrus mites. The predatory mite, *Iphidulus finlandicus* Oudms., was found to be the most numerous of the predatory mites.

Several acaricide materials as tested in the control of high populations of the Texas citrus mites proved no more effective than a processed sulphur dust when applied under drouth conditions. DN-111 spray, however, was particularly toxic in the winter application but when applied alone the material gave poor control of the rust mite. Poor control of both mites resulted from the use of 1 per cent EPN-inert dust. Ten per cent ovotran-80 per cent sulphur and 1 per cent DN-sulphur gave good initial control but spider mites increased in one to two months to high numbers again. Three per cent Aramite-inert dust gave as good control as other materials for Texas citrus mite control, but further studies with the material would be necessary to ascertain the importance of such factors as coverage and timeliness of applications in the control of rust mites. One per cent Karathane-inert dust gave poor control of rust mites on grapefruit during the spring and summer months. The material did not effectively reduce high populations of Texas citrus mites. Aramite spray was more effective than parathion, ovotran, sulphur, neotran and sulphenone spray against the Texas citrus mite in one test, but none of the materials effectively reduced heavy populations. Rain reduced the total number of Texas citrus mites but did not vary the number of infested square inch areas.

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The Importance of Parasites in the Spruce Budworm Infestations in New York and Maine

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The spruce budworm, *Choristoneura fumiferana* (Clem.), is a serious pest of spruce and balsam fir in Canada and the northeastern part of the United States and has killed an enormous amount of timber. It is also a serious pest of jack pine in the Lake States and of Douglas-fir in the Northwest. In 1951 heavy outbreaks were under way in eastern Canada, the Rocky Mountains, and the Pacific Northwest.

A heavy infestation of the spruce budworm over a wide area in the Adirodack region of New York appeared in 1945, reached a peak the following year, and declined rapidly in 1947. By 1949 budworm larvae could be found in only a few areas and in small numbers. In 1950 only six larvae were found in late June and early July throughout the Adirondack region in a survey conducted by the New York Conservation Department.

In Maine there was a definite increase in 1948 over the extremely low population that had persisted there for a number of years. In 1949 and 1950 there was a considerable increase in many localities and also a dispersion over a much larger area in northern Maine with every indication of an imminent serious outbreak. However, in 1951 there was a very definite reduction in all the study areas.

The purpose of this paper is to report studies on the natural control factors found in Maine during 1948–51, and to show that the increase of certain parasites, together with a sudden drop in the host population, was similar to what occurred in New York from 1946 to 1948. The work in Maine was conducted in plots in parts of Aroostook County.

DESCRIPTION OF PLOTS.—The study plots in Maine are 1 acre in size, 20 chains long and one-half chain wide. A trail runs through the center of each plot, and sampling is done along this line. Plots were established in representative stands of trees. The prevailing type is balsam fir, with a varying amount of hardwood mixture. Also represented are a black spruce bog, a black spruce-balsam fir mixture, and a white spruce-balsam fir mixture. One plot of mature balsam fir and red spruce was sampled for one year then eliminated by a pulpwood operation.

ESTIMATES OF POPULATION.—In order to determine the budworm populations, counts were made at different periods in the insect's development. Hibernating larvae were obtained by taking twig samples in late April or early May. These twigs were placed in cardboard boxes fitted with glass vials. When the larvae became active, they entered the vials and were counted. Counts of larvae were also made on twig samples taken after the vegetative buds had burst and started to elongate. Again, when most of the eggs had been laid, a count was made of the egg masses per twig sample. All twig samples were 15 inches long.

The numbers of budworms recorded at these three periods in the life cycle of the species in the various plots are given in table 1. It will be noted that the number of larvae found on the young shoots is much greater than the number obtained for hibernating larvae. Many of the hibernating larvae are found back of the twig sample on the larger limbs and a few even on the main trunk. These larvae, on issuing, move outward on the branches causing part of the increase noted in the shoot samples. Furthermore, all the hibernating larvae upon issuing in the boxes do not enter the glass vials. However, this method, although less reliable than the other two, gives a useful estimate early in the season for evaluation of budworm populations in the area.

PARASITES OF DIFFERENT BUDWORM STAGES.—The important primary parasites found attacking the spruce budworm in Maine were the same as those encountered in New York. Dowden *et al.* (1948, 1950) have published rather complete accounts of the budworm parasites found in New York. Discussion of the Maine data will be centered on the principal

[1] The authors acknowledge the cooperation of P. B. Dowden, in charge of the biological investigations, and the assistance of V. M. Carolin and C. O. Dirks (University of Maine).

Table 1.—Spruce budworm populations in the study plots in Maine, 1948–51. Number of larvae or egg masses per 100 twigs 15 inches long.

Plots	Hibernating Larvae				Larvae in Young Shoots				Egg Masses			
	1948	1949	1950	1951	1948	1949	1950	1951	1948	1949	1950	1951
Balsam fir:												
Cross Lake No. 1	—	36	130	87	—	169	398	452	—	48	18	5
Cross Lake No. 2	260	101	180	271	210	237	620	914	10	38	23	9
Cross Lake No. 3	—	—	123	180	—	—	256	564	—	—	18	6
Soldier Pond	—	211	258	291	—	566	740	832	—	92	41	18
Garfield	38	11	21	15	88	67	24	36	2	8	2	0
25-Mile	85	7	16	—	129	68	—	—	4	9	1	1
Madawaska Lake	—	53	111	93	—	272	—	364	—	26	36	13
DeBouillie	125	13	35	—	118	137	80	—	2	26	8	—
Wesley Brook	—	110	70	86	—	262	—	—	—	18	16	—
Wallagrass	—	—	96	28	—	—	140	100	—	—	3	—
Little Black	—	—	—	52	—	—	—	134	—	—	27	0
Black spruce:												
Cross Lake No. 1	—	—	272	78	—	—	93	44	—	—	—	—
Cross Lake Bog	—	—	5	—	—	—	27	—	—	—	1	—
White spruce:												
Soldier Pond	—	—	452	153	—	—	—	915	—	—	—	20

parasites reared and found by dissection of larvae. Table 2 gives a summary of the mortality of the spruce budworm caused by parasites in Maine. Mortality is recorded under the stage in which the host is killed. In table 3 the percentage of parasitization obtained in Maine by the various species is compared with that found in New York.

Egg Parasites.—The only egg parasite reared in Maine was *Trichogramma minutum*. In one plot parasitization of the 1949 generation of budworms by this species was unusually high, being 32 per cent; in the remaining plots it was 9 per cent or less. In the 1950 and 1951 generations the species was abundant; some plots had more than 50 per cent of the eggs parasitized. The number of eggs laid in 1951 decreased and the highest parasitization in any plot was 6 per cent.

Parasites of Fourth-Instar Larvae.—The mortality of these larvae in opening vegetative buds and on staminate flowers was much lower in Maine than New York. A small chalcid, *Dicladocerus* sp., was the most abundant parasite, although some mortality was caused by a few undetermined parasites.

Parasites of Fourth and Fifth Instars.—The three internal parsites of hibernating larvae—*Apanteles fumiferanae*, *Glypta fumiferanae*, and *Horogenes cacoeciae*—found in New York were also found in Maine. These parasites do not kill the budworm until it has reached the fourth or fifth instar. The combined parasitization of budworm larvae by *Apanteles* and *Glypta* averaged between 21 and 30 per cent for the 4 years. These percentages compared closely with those found in New York. The former was by far the most important in Maine, being 12 to 13 times more numerous than the latter in 1948 and 1950. *Horogenes* was found only occasionally.

Parasites of Full Grown Larvae.—The most important parasites of large budworm larvae were three larvaevorid flies—*Phryxe pecosensis*, *Aplomya caesar*, and *Lypha setifacies*—and the hymenopteron *Meteorus trachynotus*. Parasitization by *Phryxe* in Maine followed the same trend as in New York, decreasing with the infestation. *Aplomya*, however, was one of the few parasites in Maine that did not follow the trend recorded in New York. In Maine it remained low all four years whereas in New York it increased in importance each year. *Lypha* followed the same pattern in Maine as in New York, becoming increasingly important as the outbreak continued.

Meteorus trachynotus was recorded in every study plot in Maine each year from 1948 to 1950, but the highest parasitization in any one plot was only 5 per cent. It increased in 1951, ranging from 5 to 15 per cent. A similar increase of this species occurred in New York in 1948, after two

Table 2.—Per cent parasitization of different stages of the spruce budworm in Maine, 1948–51.

STUDY AREAS	EGGS[1] (a)	FOURTH INSTARS (b)	FOURTH AND FIFTH INSTARS (c)	FULL GROWN LARVAE (d)	PUPAE (e)	AGGREGATE
1948						
Garfield	—	4	28	24	6	51
25-Mile	—	5	29	10	9	45
DeBouillie	—	5	25	4	7	36
Cross Lake No. 2	—	3	21	8	14	39
1949						
Garfield	0[2]	6	25	13	18	50
25-Mile	0[2]	9	20	11	39	60
DeBouillie	0[2]	3	19	10	29	50
Cross Lake No. 1	9	5	18	30	30	65
Cross Lake No. 2	9	5	10	30	34	58
Madawaska Lake	9	6	16	18	33	61
Round Mountain	—	2	35	30	29	68
Wesley Brook	—	2	25	15	33	58
Soldier Pond	32	12	25	27	32	78
1950						
Garfield	27	5	17	8	17	56
25-Mile	53	—	—	12	4	60
DeBouillie	58	11	16	12	0	72
Cross Lake No. 1	16	6	38	21	17	68
Cross Lake No. 2	18	6	45	24	18	74
Cross Lake No. 3	17	3	22	13	17	55
Madawaska Lake	46	—	21	10	21	70
Wesley Brook	34	—	—	10	8	45
Soldier Pond	20	3	33	34	23	74
Wallagrass	—	7	21	26	18	55
Cross Lake Black Spruce bog	—	27	—	45	29	72
1951						
Garfield	48	0	26	36	56	89
25-Mile	64[2]	—	—	—	—	—
Cross Lake No. 1	20	1	12	38	29	70
Cross Lake No. 2	9	1	27	47	20	72
Cross Lake No. 3	32	2	25	38	31	78
Madawaska Lake	10	3	32	24	32	69
Soldier Pond	18	2	20	46	16	71
Wallagrass	48	2	25	—	—	—
Little Black	32	0	26	56	31	85

[1] Parasitization based on spruce budworm eggs laid the previous year.
[2] Based on very low counts.

years of low parasitization.

Parasites of Pupae.—Ephialtes ontario and *Phaeogenes hariolus* were the two most important hymenopterous parasites of budworm pupae in Maine. *Ephialtes* was particularly effective in the early years of the infestation; as the population declined it was less effective. The reverse was true of *Phaeogenes*. These sequences of events were similar to those observed in New York. *Itoplectis conquisitor*, which was one of the important pupal parasites in New York, was of little importance in Maine.

Agria affinis, a sarcophagid parasite of budworm pupae, was recorded in most of the plots each year. Parasitization ranged from 1 to 10 per cent, or very close to that in New York.

A hymenopterous parasite, *Exochus* sp., which was reared only occasionally in New York, was very common in 1948 in light infestations in Maine.

AGGREGATE PARASITIZATION.—The total budworm mortality, or aggregate per cent parasitization, caused by parasites in each plot was calculated from the following formula:

$$a+(1-a)b+(1-a)(1-b)c \\ +(1-a)(1-b)(1-c)d \\ +(1-a)(1-b)(1-c)(1-d)e$$

Table 3.—Per cent parasitization of the spruce budworm in New York and Maine, 1946–51.

Stage of Host Killed by Parasite Species	New York			Maine			
	1946	1947	1948	1948	1949	1950	1951
Egg:							
Trichogramma minutum (Riley)	13	1	T[1]	13	34	34	5
Fourth and fifth instar larvae							
Apanteles fumiferanae Vier.	19	15	8	24	15	28	17
Glypta fumiferanae (Vier.)	10	10	4	2	4	2	5
Mature larvae:							
Phryxe pecosensis T.T.	17	24	9	1	12	4	5
Aplomya caesar (Ald.)	5	13	32	2	4	6	4
Lypha setifacies (West.)	0	T	6	0	1	3	17
Meteorus trachynotus Vier.	1	4	11	3	3	3	9
Combined Parasitization	23	41	58	6	20	16	35
Pupae:							
Itoplectis conquisitor (Say)	8	5	3	3	1	T	T
Ephialtes ontario (Cress.)	20	13	11	3	20	6	12
Phaeogenes hariolus (Cress.)	0	T	4	1	2	7	15
Agria affinis (Fall.)	2	4	0	2	5	1	2
Combined Parasitization	30	22	18	9	28	14	29
Aggregate parasitization	62	72	75	43	61	66	76

[1] Less than 1 per cent.

where *a* is the per cent attributed to *Trichogramma; b* to *Dicladocerus* and undetermined; *c* to *Apanteles*, *Glypta*, and *Horogenes; d* to *Phryxe*, *Aplomya*, *Lypha*, and *Meteorus;* and *e* to *Ephialtes*, *Phaeogenes*, *Itoplectis*, and *Agria*. The results, given in table 2, show that there was considerable fluctuation between plots each year. However, the average of all plots tended to increase year by year. In 1948 the average was 43 per cent and did not include any egg parasitization occurring in 1947.

Other Mortality Factors.—Spruce budworm mortalities from causes other than parasites are high throughout the life cycle of the species. After hatching in August and when issuing from hibernacula the following spring, many of the tiny larvae are borne away by air movements. Some are preyed on by mites and spiders. While the larvae are in hibernation the principal decimators are predators during late summer and fall and desiccation throughout the whole period. Experiments for three successive years indicate that total mortality from egg hatching until needle mining averaged 70 to 80 per cent, with 29 to 41 per cent occurring in the hibernacula.

When budworm larvae are larger and exposed, they are fed upon by many species of birds. Studies were initiated in 1949 to obtain an estimate of the importance of bird predation. Some small balsam trees were enclosed in cages, and several caged and uncaged trees were artificially infested with budworm eggs. Some of these cages were covered with wire screening to prevent the entry of birds but to permit the entry of parasites; other were covered with cloth to prevent the entry of both birds and parasites. In the screen wire-covered cages 3.8 per cent of the eggs produced moths; in the cloth-covered cages 15.4 per cent survived. In contrast, only 1.2 per cent of the eggs on the uncovered trees produced adults. These studies were repeated in 1950–51, and the results corroborated those obtained in 1949–50. It was found that survival was 8.5 per cent on trees in screen-covered cages, 12.4 per cent on trees in cloth-covered cages, and 0.1 per cent on uncovered trees.

Discussion.—In New York a spruce budworm outbreak arose very suddenly in 1945, reached a peak the following year, and declined rapidly in 1947. In Maine an outbreak began in 1948, reached a peak in two years, and began to decline in 1951. The cycle of events in these outbreaks has been strikingly similar. The effectiveness of certain parasites showed

a remarkably similar trend in both regions. *Apanteles fumiferanae*, *Glypta fumiferanae*, *Horogenes cacoeciae*, and *Agria affinis* accounted for almost the same budworm mortalities in both areas. *Trichogramma minutum*, *Phryxe pecosensis*, *Ephialtes ontario*, and *Itoplectis conquisitor* decreased in effectiveness, but *Lypha setifacies*, *Meteorus trachynotus*, and *Phaeogenes hariolus* increased in effectiveness as budworm populations declined. These studies may indicate that population trends of certain parasites are indicative of the trend in host population.

The budworm population in the Adirondacks has remained at a very low level since the end of the outbreak in 1947. No prediction can be made as to the duration of its present level, but surveys will be continued. In Maine there was a distinct decline in the intensity of infestation in 1951. The Maine outbreak cannot be considered over, but owing to increased parasitization and other natural control factors it is believed that the budworm population will continue to decrease in 1952 as it did in New York in 1948. In Maine, however, a sizeable population remains over a large area. It should be emphasized that the danger of another outbreak in Maine in the near future cannot be overlooked, as there is also the possibility of heavy moth flights from the severe outbreaks now in existence in nearby Canada.

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Ecological Tests on *Chrysolina gemellata* (Rossi) and *C. hyperici* Forst. in the Biological Control of Klamath Weed[1,2]

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Holloway & Huffaker (1951) reported the progress of Klamath weed control in California by the imported beetle, *Chrysolina gemellata* (Rossi), emphasized the role of synchronization in accounting for that control, and described a condition of asynchronization as the paramount factor accounting for the lack of control by the closely related species, *C. hyperici* Forst. Experimental data not included in that paper, but supporting and extending the basic interpretation, have now been completed. They stated, "As a result of its delay of reproductive activities in the fall, the developmental phase of the brood of *Chrysolina hyperici* is projected so far into the summer that the dry soil conditions that prevail from about April to October destroy the great mass of the population."

Three potential factors, in addition to the simple lag in reaction to the moist conditions in the fall, coupled with the dry soil factor, were considered as possibly contributing to the difference in effectiveness of these two otherwise ecologically and phylogenetically similar beetles. One was that the plant foliage in late spring and early summer (at a time of abundant larval feeding of *Chrysolina hyperici*, but after the larval brood of *C. gemellata* has completed feeding) becomes tough or otherwise unsuitable. A second idea was that, once deposited, the eggs and resultant larvae of *C. hyperici* might develop very slowly, compared to *C. gemellata*, and the brood of *C. hyperici* would be correspondingly projected into the unfavorably dry soil period of late spring and early summer. The third possibility concerned the aestivating propensities of the two species. It was thought that predatory or parasitic action would not be sufficiently

[1] This cooperative project between the Bureau of Entomology and Plant Quarantine of the U. S. Department of Agriculture and the Division of Biological Control of the University of California, was, until March 1952, under the coordinating supervision of J. K. Holloway (now in Spain), and some of the ideas and leads indicating need for certain of the tests were his. Thanks are also due Mr. C. H. Spitzer, Jr. for making many of the observations on development at different temperatures.

The nature of the replacement vegetation following removal of the weed by beetles was reported by Huffaker (1951).

[2] *Hypericum perforatum*.

[3] Also Collaborator with the U.S.D.A., Agricultural Research Administration, Bureau of Entomology and Plant Quarantine.

Table 1.—Developmental time of *Chrysolina gemellata* and *C. hyperici* at three levels of temperature.

Species	Mean Time in Days		
	Incubation	Larval and Pupal	Total
C. gemellata	27 at 52.8° F.	118 at 51° F.	145 at 51° F.
C. hyperici	32 at 52.4° F.	105 at 51° F.	136 at 51° F.
C. gemellata	24¾ at 54.0° F.	106 at 54° F.	131 at 54° F.
C. hyperici	25¼ at 54.0° F.	93 at 54° F.	119 at 54° F.
C. gemellata	6½ at 77.3° F.	25½ at 77.5° F.	32 at 77.5° F.
C. hyperici	6¾ at 77.3° F.	26½ at 77.5° F.	33 at 77.5° F.

selective between the two species to represent an important consideration.

The three possibilities were tested experimentally. Also, actual counts of eggs from caged beetles demonstrate quantitatively the delay in egg deposition by *Chrysolina hyperici* under field conditions.

Suitability of Plant Foliage.—In 1947 tests were conducted to appraise the importance of condition of foliage. One group of Klamath weed plants had been kept under outdoor conditions at Albany until flowers were produced in June. The basal foliage of these plants had completely dropped and the foliage of the flowering risers was toughened, yellowish-green to purplish in color, and generally of the type upon which larvae in the field would be forced to feed if their development were curtailed until that time of year. If this type of food were unsuitable, it would offer an explanation, supplementary to the dry soil condition, of the differences in success of *Chrysolina gemellata* and *C. hyperici*. The foliage for the control group of larvae was obtained from lush basal growth which continued developing on the control group of host plants as a result of frequent removal of all flowering risers as they appeared. This type of foliage is the typical food of larvae under natural conditions during the late fall, winter and early spring. Both types of foliage were clipped and placed in containers with the larvae as needed. A total of 28 young larvae were used with each foliage condition.

There was no significant difference in the numbers which completed development and there was only a slight difference in the speed of the development of the two groups, but not sufficient to present this as a factor of importance. Twelve larvae of the group fed old, discolored foliage emerged as adults, compared to eleven of the group fed lush, green basal foliage. There was an undesirable mortality of each group apparently due to a disease which was not identified. Other tests of a similar nature carried out on potted plants under outdoor conditions gave similar results. In that case 17 young larvae were used for each condition. Six adults of the discolored foliage group emerged, and 5 of those in the lush green foliage group. The rate of development was little different.

Temperature and Development.—During the winter of 1950–51, both *Chrysolina gemellata* and *C. hyperici* were reared at three different temperature levels. Unfortunately, ideal temperature-controlled facilities were not available, but the results are fully adequate to support the general conclusions. A total of 15 eggs of each species was started under each temperature level. Due to mortality during development (independent of temperature), in some cases only 4 or 5 individuals emerged as adults, but the time span involved for the few individuals is very probably typical.

One group was placed in a refrigerator which maintained a temperature of 48° to 54° F. One group was run under outdoor conditions, and a hygrothermograph record furnished the data from which the approximate mean temperature for that group was determined. The third group was reared in an insectary at a temperature which was closely controlled at 77.5° F.

Table 1 (and the data for the individual insects, not herein presented) shows that the incubation period of *Chrysolina hyperici* was slightly slower than that of *C. gemellata* at all temperatures used. This was a consistent reaction, but the degree

of difference was very small at the highest temperature. On the other hand, the table shows also that *C. hyperici* developed from the newly-deposited egg to the adult somewhat faster than did *C. gemellata*, except at the highest temperature. At that temperature, the results were very comparable. The post-embryonic development of *C. hyperici* was as consistently faster than that of *C. gemellata* as was the embryonic development slower. In fact, the lag in incubation of *C. hyperici* eggs was more than compensated during the larval and pupal development. At the two lower temperatures, *C. hyperici* passed the larval and pupal stages about 13 days faster than did *C. gemellata*. This was not so at 77.5° F.

These data therefore show that a differential in the speed of development of the immature stages of these two beetles, according to prevailing temperatures, is not a contributive influence toward the climatic asynchronization of *Chrysolina hyperici*, compared to *C. gemellata*.

AESTIVATION MORTALITY.—On May 30, 1951 tests were arranged to study the natural mortality of *Chrysolina gemellata* and *C. hyperici* under identical field conditions in El Dorado County. A demonstration that *C. hyperici* could not survive the required long dry period in aestivation from June to October, or that it could survive only in very small numbers, compared to *C. gemellata*, would make obvious the importance of this factor. Fully-fed, pre-aestivating adults of each species were placed in screened cages in typical stands of Klamath weed, and the survivors were recorded at stipulated times. Four field cages, each 4 by 4 by 3 ft., were anchored about 3 inches in the ground. Fourteen-mesh screen wire was used as covering instead of cloth in order to maintain more natural conditions within the cages. One hundred *C. gemellata* were placed in each of 2 cages, one of which was checked after 2 months and the other after 4.5 months. The same was so with *C. hyperici*.

Of the physical factors, the maximal temperature would be expected to exert the most profound influence on survival during aestivation of *Chrysolina hyperici*, a native of Great Britain and northern Europe. The highest temperature recorded during the summer by the U. S. Weather Bureau station at Placerville, California was 104° F. on July 19 and again on July 20. Temperatures from 100° F. to 102° F. were recorded on certain days in July, August and September. The mean of the daily maxima from June 1 to September 30 was 90.9° F. This information serves only to emphasize the rather high temperature survived by both species, particularly interesting with regard to *C. hyperici*.

The recovered survivors (as a percentage of 100 individuals in each case) from May 30 were as follows:

	July 31	*October 10*
Chrysolina gemellata	37	21
C. hyperici	45	38

At the end of both the 2-months and the 4½-months periods, *C. hyperici*, contrary to expectation, considering that *C. gemellata* is the insect of the warmer and drier Mediterranean region, survived better than did *C. gemellata*. A part of the loss was undoubtedly due to action of spiders, ground beetles and other predators; hence, the results do not mean that this difference is significant solely with respect to meteorlogical factors. It does mean that survival during aestivation at a dry, hot location is not a potent element accounting for the contrast between the two species as weed control agents here. Contrary to the known status, if taken alone, the data would indicate *C. hyperici* as the one most capable of success. The numbers of both species surviving this period were sufficient to maintain a good population and, considering the huge egg-laying propensities, to permit rapid multiplication.

RESPONSE TO FALL RAINFALL AND EGG DEPOSITION.—On October 11, 1951 two of the cages used in the aestivation tests were continued in order to determine the rapidity with which the two species come out of aestivation and the numbers of eggs laid by them after the beginning of the fall rainy season. One cage was stocked with 25 *Chrysolina gemellata* and the other with 34 *C. hyperici*. Although nearly an inch of rain had fallen prior to October 11, no eggs of either species were found in the aestivation cages. Only a slight evidence of feeding by *C. gemellata* was observed. Hence, the tests were begun prior to any egg deposition by the test insects. Approximately each month (or 5 weeks), a very close count was made of the eggs in each cage. All eggs (or larvae if the eggs had hatched) were removed from the

cage at each count. Rainfall was abundant from late October throughout the winter and early spring. The results are shown in table 2.

The results in table 2, considered in the light of known delays in the rains much beyond early October in many parts of California during typical years, and known appearance of dry soil conditions as soon as late March or early April, statistically reveal the great difference in synchronization of these two species. During the very first month immediately following the first substantial rains, *Chrysolina gemellata* reached a high level of egg deposition, maintained that high level throughout each of the winter months, and increased its production somewhat in February and March. In contrast, *C. hyperici* did not reach an appreciable level of egg deposition until the fourth month following the same early rain, and, actually, did not attain an equally comparable high level until the fifth month, although it did so then. This species deposited large numbers of eggs only in February and March.

Table 2.—Egg deposition per beetle from an initial number of 34 *Chrysolina hyperici* and 25 *C. gemellata* (survivors through aestivation of 100 adults of each from May 30) at monthly intervals from the middle of October 1951 to the middle of April 1952.

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Total
Chrysolina gemellata	24	23	24	28	40	Nil	139
Chrysolina hyperici	Nil	3	6	18	23	Nil	50

Many field observations during the past 6 years have indicated that eggs deposited in February and March must encounter atypically moist soil conditions far into the spring in order for the maturing brood to pupate successfully. Hard dry soil surfaces, even with ample subsurface moisture, are inimical.

The year of these tests was an unusually wet one, rains occurring at the test location prior to typical and in above-normal quantities. The soil dries in many locations in California to a point which is inimical to pupation by April 15 or even earlier for periods of 2 weeks or more. Such periods would be adequate in length to prevent many larvae from entering the soil upon maturing. Hence, generally, the largest successful entrance of the soil prior to pupation occurs by or before mid-April, and, in fact, pupal development has been well advanced, or adults appearing by this time, in the areas where the most rapid multiplication rates have been experienced. The large amount of thermal units, expressed in effective hour-degrees of temperature, required for these species to reach the pupal stage, considered in the light of these data on egg deposition, emphasize the great disadvantage of *Chrysolina hyperici*. Even allowing that internal insect temperatures may be much above recorded U. S. Weather Station temperatures, the majority of the eggs of this species (much fewer also in total number), are deposited too late in the spring to permit full development before adverse dry soil conditions ensue.

SUMMARY.—Experimental data are presented supporting and extending the idea of synchronization of *Chrysolina gemellata* (Rossi) and asynchronization of *C. hyperici* Forst., as the paramount factor explaining successful control of Klamath weed in California by the former species and the lack of control by the latter. Actual counts of eggs deposited by the two species under field conditions showed that *C. hyperici* reaches full egg deposition about 3 months later than does *C. gemellata* following the first substantial fall rain. Suitability of plant foliage in early summer, rates of development of eggs and larvae, and survival of long periods of summer drouth and high temperatures during aestivation were studied as potential factors of importance in further explaining the difference in effectiveness of these two beetles as weed control agents. The two species showed no appreciable differences in capacities or reaction regarding any of these points. The conclusion is fully confirmed, therefore, that the factor of paramount importance is the delay in egg deposition by *C. hyperici*, compared to *C. gemellata*, following the first substantial rain in the Fall, and the consequent projection of the brood into the period of dry soil conditions during the subsequent Spring.

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The Repellency of Chlordane, DDT, and Other Residual Insecticides to Greenhouse Thrips

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The repellent properties of residual insecticides have long been of interest to economic entomologists because repellency is sometimes of considerable importance in increasing or decreasing the effectiveness of an insecticide under field conditions. An insecticide which under laboratory conditions may be highly toxic to a particular insect may prove to be ineffective under field conditions because of a high repellency factor which causes the insect to depart before it has taken up a lethal dose. On the other hand an insecticide which may be only moderately toxic to a certain pest or slow in its action, may prove highly effective under field conditions if a low repellency factor permits the insect to take in lethal quantities before being disturbed. Uniformity of deposit is in general of greater importance in an insecticide with high repellency characteristics than in one which is relatively non-repellent. Similarly the efficiency of a repellent residual insecticide is increased as the area under treatment is enlarged. Thus while under certain conditions a highly repellent insecticide may have low efficiency in demonstrating its toxicity, under other conditions the repellency itself may be sufficient to insure protection from a particular pest.

The present study[2,3] was undertaken to obtain comparative quantitative data on the repellent characteristics of several residual insecticides. It was decided that a detailed examination of the effects of known concentrations of various residual insecticides on the behavior of a single species of insect could serve as a pilot effort. Further work on other species of insects could then provide a basis for tailoring insecticides for specific needs.

The term repellency will be used in this paper to refer to any complex of stimuli, chemical or physical, which results in a smaller population of insects remaining in contact with a treated surface than would otherwise be the case if a surface in question were not treated. This is essentially the definition accepted by Dethier (1947) and by Kennedy (1947).

REVIEW OF LITERATURE.—The earlier references in the literature to insecticide repellency were primarily concerned with the arsenicals, as for example the paper of Moore (1922) which dealt with the repellency of arsenical spray deposits to the Japanese beetle, *Popillia japonica* Newm. Following the advent of DDT and other residual insecticides, the question of repellency has been repeatedly raised. Buxton (1945) stated that DDT "does not act as a repellent, so far as is known." This statement has been the basis for the widely held belief that DDT is completely non-repellent. Thus Dethier (1947) states that DDT has "no repellent qualities whatsoever." It has also been frequently stated that chlordane is non-repellent.[4]

That DDT and similar insecticides do have some repellent qualities has been noted many times in recent literature, but very few quantitative experiments have been reported. Metcalf *et al.* (1945) showed that DDT has definite repellency to the common malaria mosquito, *Anopheles quadrimaculatus* Say, and that "mosquitoes must actually rest upon DDT treated surfaces in order to be repelled by it." Gahan, *et al.* (1945) also detected an excitatory response by the common malaria mosquito to DDT treated surfaces. These authors concluded, however, that repellency occurs only after a lethal quantity of insecticide has been absorbed. On the other hand Kennedy (1947) found that mosquitoes, *Aëdes aegypti* (L.) and *Anopheles maculipennis atroparvus*, van Thiel, are sufficiently excited by sub-lethal contacts with DDT to cause considerable undirected movement.

Wolcott (1945) showed that DDT treated wood is repellent to the West Indian dry-wood termite, *Cryptotermes brevis* (Walker). Loeffler & Hoskins (1946)

[1] The data for this paper were assembled in the laboratories of the University of California Citrus Experiment Station at Riverside, California.

[2] This project was financed in part by a research grant of the Velsicol Corporation of Chicago, Illinois.

[3] Some of these data were presented at the Pacific Slope Branch meetings of the A.A.E.E. in June, 1947.

[4] Velsicol Corporation. "Velsicol 1068" Tech. Info. Bull. 201 (revised) 1948.

detected moderate repellency toward DDT for third instar blowfly larvae, *Phaenicia sericata* (Meig.), but no significant repellency toward *gamma* benzene hexachloride. Cragg (1946) indicated that the success of DDT in controlling sheep blowflies, *P. sericata*, is due to the repellency of that compound and the resultant prevention of oviposition.

Olson & Dahms (1946) noted what appeared to be significant repellency of DDT to the tropical rat mite, *Liponyssus bacoti* (Hirst). Askelöf (1950), without presenting data, ascribed a repellent effect of DDT and BHC to bloodsucking insects on livestock. Chang (1948) observed a repellent action of BHC to the green peach aphid, *Myzus persicae* (Sulz.). Weinman & Decker (1949) were unable to detect any repellency of either aldrin or parathion to grasshoppers.

Linsley & MacSwain (1947) presented data that indicate that DDT exhibits significant repellency toward honey bees, *Apis mellifera* L., working in alfalfa fields. On the other hand Musgrave (1951) concluded that DDT at standard recommended rates of application has at most a slight, temporary repellent action on honey bees. Weaver (1951) found that chlordane exhibits high repellency toward bees working in sprayed cotton blossoms, that BHC also shows significant repellency, but that DDT or toxaphene have little repellency to these insects.

MATERIALS AND METHODS.—One per cent (w/v) acetone solutions were prepared from distilled chlordane, b.p. 175° C./2mm. Hg; *p,p*[1]-DDT, m.p. 109° C.; parathion, tech.; heptachlor, m.p. 86 to 88° C.; *gamma* benzene hexachloride (lindane), m.p. 112° C.; dimethyl phthalate, tech.; and certain other compounds as specifically noted. Successively lower concentrations were derived by dilution of the one per cent solutions.

Greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouché) from a laboratory culture maintained on oranges and kept at constant temperature and humidity, were used in these experiments. Test preparations consisted of discs, seven centimeters in diameter, cut from avocado leaves. These were coated on one half of each upper surface (by pipette) with 0.1 milliliter of acetone solution containing various concentrations of insecticide plus one milligram per milliliter of a red, fat soluble dye (the absorption characteristics of which were close to those of oil red "O") to serve as a guide to the location of the insecticidal residue. In figure 1 the untreated leaf half is represented at A, the treated half at B.

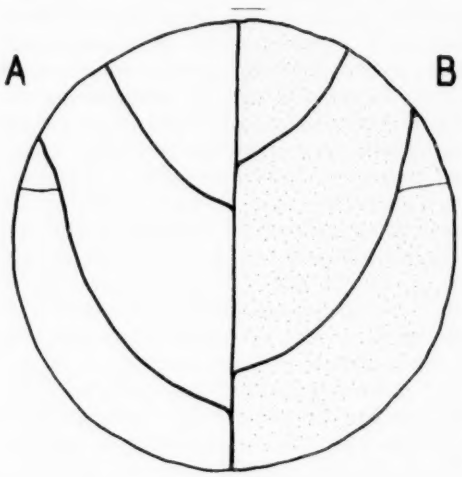

FIG. 1.—Diagram of treated avocado leaf disc, side A untreated, side B coated with insecticide plus dye.

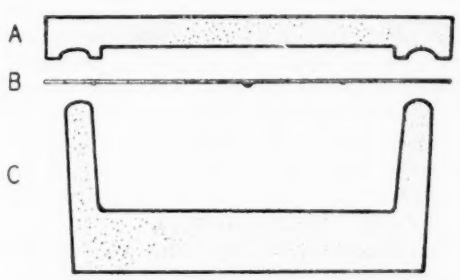

FIG. 2.—Diagrammatic section through standard thrips-avocado leaf repellency preparation. A—cover of short stender. B—avocado leaf disc. C—short stender. Thrips are free to move in space between A and B.

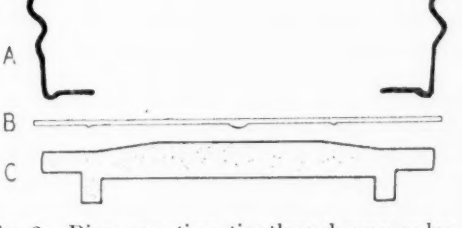

FIG. 3.—Diagrammatic section through vapor-reducing thrips-avocado leaf repellency preparation. A—metal rim of mason jar closure. B—avocado leaf disc. C—glass top of mason jar closure. Air penned by A was disturbed by a mild draft from an electric fan.

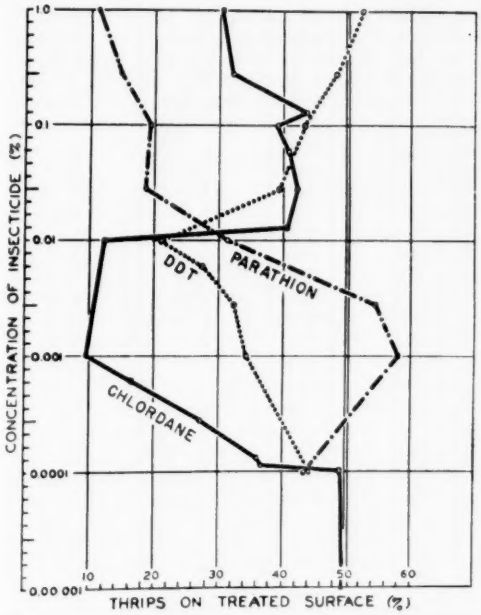

FIG. 4.—Variation of repellency with differing concentrations of chlordane, DDT, and parathion as described in table 1. Repellency is measured by lowered proportion of thrips remaining on treated surface. The concentration at which only 30 per cent of the thrips remain on the treated surface is the basis for comparing the repellency characteristics of these insecticides. Compare with figure 5.

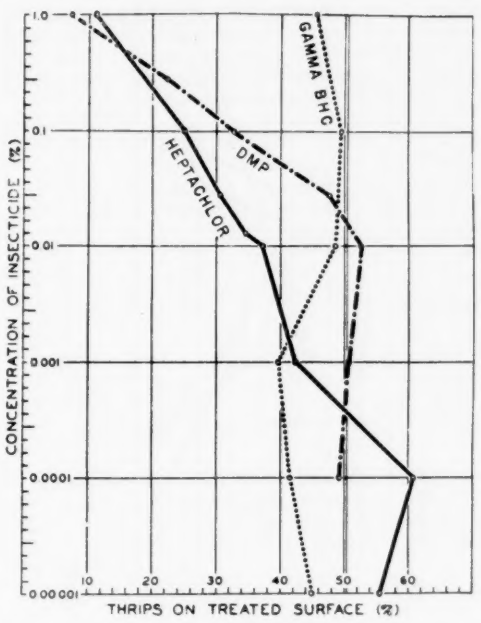

FIG. 5.—Variation of repellency with differing concentrations of heptachlor, dimethyl phthalate (DMP) and *gamma* benzene hexachloride (γBHC) as described in table 1. Compare with figure 4.

Each treated leaf disc was infested with about 35 adult thrips and placed between the cover and dish of a short stender, the components being held together tightly by elastic bands (figure 2). These preparations included above each leaf a small enclosure from which the thrips could not escape but in which they could move freely and be observed easily. To eliminate fumigation effects of benzene hexachloride, the leaf-discs for these experiments were held between rims and tops of mason jar closures as shown in figure 3. A slow current of air from an electric fan was used in an effort to prevent accumulation of benzene hexachloride vapors in these test preparations. A strong light directly overhead tended to eliminate phototactic variation during the course of all of the experiments.

After an hour, the thrips on the treated and untreated halves of the discs were counted. The percentage of thrips on the treated surfaces constituted the criterion of repellency. Hence the greater the degree of repellence, the lower the proportion of thrips remaining on the treated surface. Thus repellency as used here refers to the factor or factors which increase movement of the thrips, the greater the degree of movement the less likelihood of thrips remaining on the portion of the lear which elicits such movement.

RESULTS.—In the course of these investigations 1040 leaf disc preparations were made and the reactions of 46,637 insects were noted. A summary of the data obtained is presented in Tables 1 through 7, and these data are shown in figures 4 through 7.

In the absence of either repellence or attractance, the percentage of thrips on either the treated or untreated halves of the leaf discs would be expected to average 50 per cent. In the 115 check replicates (using acetone plus dye, but no insecticide), the percentage of thrips on the treated surfaces was actually 47.86 per cent, with a standard deviation of 15.43 per cent. Using these figures as a guide, repellency was arbitrarily considered to have been demonstrated when less than 30 per cent of the thrips remained on the treated surface. Relative degrees of repellency for the solutions tested are shown in table 8.

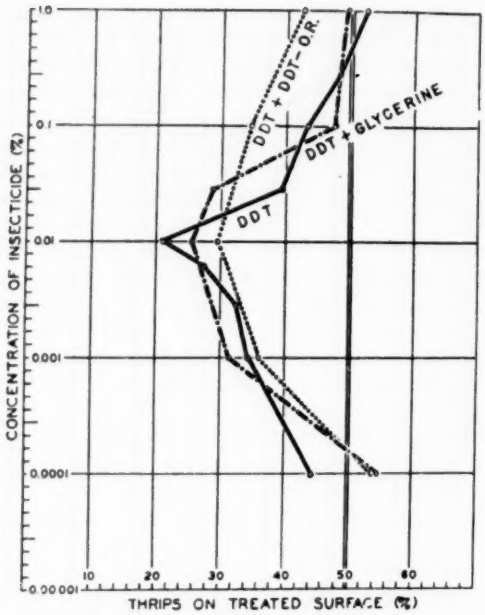

FIG. 6.—Variation of repellency with differing concentrations of DDT, DDT plus DDT oily residue, and DDT plus glycerine. Compare with figure 7.

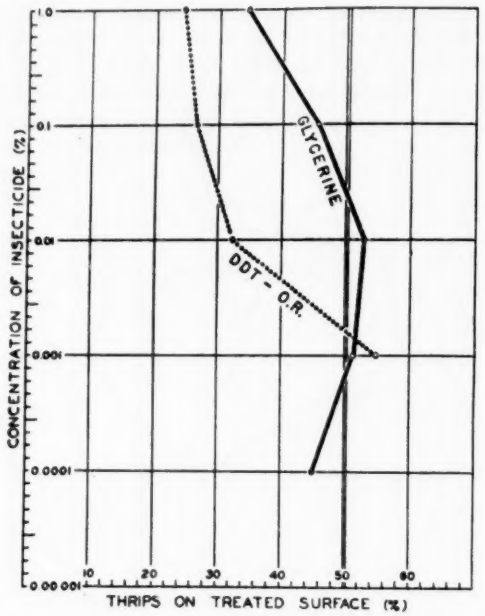

FIG. 7.—Variation of repellency with differing concentrations of DDT oily residue and glycerine. Compare with figure 6.

An examination of the data reveals that of the chemical agents and combinations tested, chlordane is repellent at the lowest concentration. At successively higher concentrations DDT, parathion, heptachlor, and dimethyl phthalate show corresponding evidence of repellency. *Gamma* benzene hexachloride fails to show significant evidence of repellency by this technique.

The possibility of the physical state of the materials being an important factor in these tests was considered. An attempt was made to modify the physical state of the DDT by adding equal quantities of glycerine in one series, and DDT oily residue (a non crystallizable residue from the manufacture of DDT: Haller *et al.* 1945) in another series to inhibit the crystallization of DDT from the acetone solution. Repellency of these two agents, when used alone, was also obtained for

Table 1.—Per cent of greenhouse thrips remaining on various concentrations of chlordane residues on treated halves of avocado leaf discs. The 1 per cent concentration is equivalent to a deposit of approximately 50 micrograms per cm².

Conc. (Per Cent)	No. of Replicates	Total Thrips Counted	Per Cent on Treated Surface
1.0	40	1610	30.3
0.5	10	381	32.0
0.2	10	403	43.7
0.1	45	1738	39.0
0.08	10	370	40.8
0.05	10	283	42.1
0.02	10	290	40.3
0.01	25	1062	12.1
0.001	25	928	9.6
0.0008	25	836	16.6
0.0005	35	1229	27.1
0.0002	30	1309	36.0
0.00015	25	1282	36.8
0.0001	25	884	49.2
0.00001	25	762	49.5
0.000001	20	740	51.5

Table 2.—Per cent of greenhouse thrips remaining on various concentrations of DDT residues on treated halves of avocado leaf discs. The 1 per cent concentration is equivalent to a deposit of approximately 50 micrograms per cm².

Conc. (Per Cent)	No. of Replicates	Total Thrips Counted	Per Cent on Treated Surface
1.0	10	410	52.2
0.5	5	218	48.2
0.1	5	252	48.3
0.05	5	281	39.3
0.01	30	1327	21.0
0.008	20	778	27.2
0.005	20	889	32.3
0.001	25	1023	34.2
0.0001	5	206	44.2

Table 3.—Per cent of greenhouse thrips remaining on various concentrations of parathion residues on treated halves of avocado leaf discs. The 1 per cent concentration is equivalent to a deposit of approximately 50 micrograms per cm².

Conc. (Per Cent)	No. of Replicates	Total Thrips Counted	Per Cent on Treated Surface
1.0	10	506	11.1
0.5	10	492	14.8
0.1	10	494	19.6
0.05	20	1009	18.6
0.01	20	1070	31.4
0.005	10	480	54.4
0.001	5	242	58.0
0.0001	5	288	43.8

Table 4.—Per cent of greenhouse thrips remaining on various concentrations of heptachlor residues on treated halves of avocado leaf discs. The 1 per cent concentration is equivalent to a deposit of approximately 50 micrograms per cm².

Conc. (Per Cent)	No. of Replicates	Total Thrips Counted	Per Cent on Treated Surface
1.0	15	487	11.1
0.1	25	941	25.0
0.05	10	339	30.4
0.02	10	385	34.5
0.01	40	1362	37.1
0.001	20	755	42.3
0.0001	5	176	60.9
0.00001	5	155	54.8

Table 5.—Per cent of greenhouse thrips remaining on various concentrations of *gamma* benzene hexachloride residues on treated halves of avocado leaf discs. The 1 per cent concentration is equivalent to a deposit of approximately 50 micrograms per cm².

Conc. (Per Cent)	No. of Replicates	Total Thrips Counted	Per Cent on Treated Surface
1.0	5	200	45.6
0.1	5	192	49.5
0.01	15	397	48.6
0.001	15	362	39.8
0.0001	15	527	41.7
0.00001	15	597	44.9

purposes of comparison. It can be seen in table 7 and figures 6 and 7 that there is an apparent effect on the DDT repellency due to the addition of the other agents and that this difference cannot be explained by merely adding the effect of the two chemicals since this would give results contrary to the data. The order of magnitude of the repellency change, however, is not sufficiently great to cause an overlap of DDT repellency with that of any of the other insecticides tested.

Table 6.—Per cent of greenhouse thrips remaining on various concentrations of dimethyl phthalate residues on treated halves of avocado leaf discs. The 1 per cent concentration is equivalent to a deposit of approximately 50 micrograms per cm².

Conc. (Per Cent)	No. of Replicates	Total Thrips Counted	Per Cent on Treated Surface
1.0	10	590	7.3
0.5	5	226	22.1
0.1	5	244	32.7
0.05	5	237	47.7
0.01	10	546	52.6
0.001	5	262	50.8
0.0001	5	275	49.1
0.000001	5	266	51.5

Table 7.—Per cent of greenhouse thrips remaining on various residues on treated halves of avocado leaf discs. The 1 per cent concentration is equivalent to a deposit of approximately 50 micrograms per cm².

Material	Conc. (Per Cent)	No. of Replicates	Thrips Counted	Per Cent on Treated Surface
DDT plus DDT Oily Residue*	1.0	5	253	42.3
	0.1	5	227	34.6
	0.01	35	1819	29.7
	0.001	15	792	36.0
	0.0001	5	262	53.8
DDT plus Glycerine	1.0	5	347	49.4
	0.1	5	354	47.5
	0.05	20	1417	28.8
	0.01	25	1352	25.5
	0.001	40	2804	31.4
	0.0001	15	1161	54.4
DDT Oily Residue*	1.0	5	196	24.5
	0.1	5	283	26.8
	0.01	5	241	32.3
	0.001	5	279	54.9
Glycerine	1.0	5	379	34.4
	0.1	5	407	45.5
	0.01	5	324	52.8
	0.001	5	241	51.1
	0.0001	5	393	45.0

* A non-crystallizable residue from the manufacture of DDT.

The reliability of these repellency tests was checked by applying the "chi²" method and the "t" test of significance to the difference between two concentrations of chlordane, the figures for 0.0001 and 0.0002 per cent. Both methods indicated less than a 1 per cent possibility that these differences were due to chance alone.

DISCUSSION.—The behavior of the greenhouse thrips on the chlordane or DDT treated leaf discs sheds some light on the nature of the repellency herein considered. It will be noted (Fig. 4) that

Table 8.—Relative degree of repellency of the compounds studied (based on interpolated concentrations at which 30 per cent of the greenhouse thrips remained on the treated halves of avocado leaf discs).

MATERIAL	CONCENTRATION FOR EQUIVALENT EFFECT (Per Cent)	CONCENTRATION FOR EQUAL REPELLENCE
Chlordane	0.0004	1.0
DDT plus glycerine	0.003	7.5
DDT	0.006	15.0
DDT plus oily residue	0.0095	24.0
Parathion	0.015	37.5
DDT oily residue	0.045	112.5
Heptachlor	0.05	125.0
Dimethyl phthalate	0.2	500.0
γ benzene hexachloride		Not reached
Glycerine		Not reached

as the concentration of either of these insecticides increases, fewer and fewer thrips are found on the treated surfaces until a minimum point is reached. Further increase in insecticide concentration, however, results in a greater number of thrips being found on the treated surface, an apparent lowering of repellency being indicated. At still higher concentrations of chlordane (0.5 per cent, 1.0 per cent) there is evidence of a partial increase of repellency. A hypothesis that can explain these repellency shifts involves the realization that greenhouse thrips are relatively sedentary insects, and that if conditions are suitable for feeding only slight movement is evident. The presence of a sufficient concentration of some of the chemicals tested can excite the insects or at least prevent them from resting where they are. This higher degree of random movement on the treated half of the leaf disc, relative to the untreated half, would result in a smaller proportion of the thrips being found at the time of counting on the treated portion of the leaf.

At higher concentrations of insecticide, toxicity perhaps enters the picture, with most of the thrips that become moribund being unable to find their way to safety before succumbing to the effects of the poison. Some of the insects, however, might accidentally reach the untreated surface while others originally on the untreated surface might accidentally move on to the treated half, and once having arrived, be unable to leave except by chance because of the lack of any basis for orientation.

The explanation for the apparent slight increase of repellency of chlordane at the 0.5 per cent and 1 per cent concentration might be that at this high a concentration of insecticide any thrip moving from the untreated to the treated half becomes excited and repelled before moving entirely on to the insecticide, thus experiencing the narrow concentration gradient of the borderline between the treated and untreated halves of the avocado leaf disc. The reason for this phenomenon appearing only in connection with chlordane treatment might have been due to its comparatively high repellency.

The failure to demonstrate repellency for benzene hexachloride may be due either to an actual lack of such qualities or to ineffective removal of the vapors of this insecticide despite attempts to eliminate this factor.

Toxicity data for greenhouse thrips are not available for all of the chemical agents tested, though Metcalf (1947) and Rogoff & Metcalf (1951) gave figures for *gamma* benzene hexachloride, heptachlor, DDT, and chlordane. These authors demonstrated decreasing toxicity in the order named. Thus the repellency of *gamma* benzene hexachloride, haptachlor, DDT, and chlordane toward the greenhouse thrips is in an inverse relationship to the toxicity.

SUMMARY.—1. Of several residual insecticides tested for repellency toward greenhouse thrips, chlordane was repellent at the lowest concentration. Corresponding evidence of repellency was shown for successively higher concentrations of DDT, parathion, heptachlor, and dimethyl phthalate. No significant evidence of repellency was demonstrated for *gamma* benzene hexachloride.

2. An inverse relationship was noted between the degree of repellency and the order of toxicity to greenhouse thrips of most of the chemicals tested.

3. An attempt to change the physical state of DDT deposits by inhibiting crystallization did change the repellency characteristics of these deposits. The order of magnitude of these repellency changes, however, was not sufficiently great to cause an overlap of DDT repellency with that of any of the other insecticides tested.

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Reduction of Oriental Fruit Moth in Peach Orchards by Use of Parathion and EPN to Control Plum Curculio

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During 1950 and 1951 a study was made of the effect of parathion and EPN spray schedules for control of the plum curculio (*Conotrachelus nenuphar* (Hbst.), on the oriental fruit moth, *Grapholitha molesta* (Busck), population in peach orchards near Moorestown, N. J.

The reduction of first-brood oriental fruit moth larvae in peach drops and twigs by a parathion spray schedule to control the plum curculio was reported by Driggers (1949). Bobb (1951) reported that the first-brood infestations in peach drops and twigs were reduced greatly by parathion and EPN spray schedules to control the plum curculio and that fruit injury at harvest was exceedingly low in experimental plots.

MATERIALS.—Parathion was used at the rates of 2 and 1.6 pounds of 15 per cent wettable powder and EPN at the rate of 1.5 pounds of 25 per cent wettable powder per 100 gallons. Sprays were applied at shuck split and approximately 10 and 20 days after shuck split. The spray schedule generally used for plum curculio on peach consists of an application at shuck split followed by another 10 days later. The second application after shuck split was included in these observations, since oriental fruit moth adults of the overwintering brood are abundant in orchards near Moorestown on June 1, or about 20 days after the shuck-split spray is applied. In 1950 sprays were applied to three experimental orchards between May 13 and 16, May 23 and 24, and June 2 and 5, and in 1951 to five experimental orchards between May 4 and 9, May 14 and 21, and

[1] E. L. Plasket assisted in the field work.

Table 1.—Moths caught in traps in peach orchards sprayed with parathion, EPN, and lead arsenate in 1950 and 1951.

Date Examined	Date of Spraying and Number of Moths						
	Parathion		EPN		Lead Arsenate (control)		
	Orchard		Orchard		Orchard		
	1	2	1	2	1	2	3
			1950				
April 31–May 6	—	—	—	—	22	14	49
		May 13					
7–13	166	153	—	—	87	122	167
	May 16						
14–20	30	26	—	—	44	19	88
	May 24	May 23					
21–27	11	5	—	—	71	165	77
		June 2					
28–June 3	22	0	—	—	37	248	75
	June 5						
June 4–10	13	3	—	—	45	151	98
11–17	2	0	—	—	5	46	20
18–24	4	1	—	—	29	33	103
25–July 1	5	6	—	—	91	430	345
July 2– 8	11	6	—	—	114	1,387	290
9–15	14	13	—	—	98	964	245
16–22	21	14	—	—	95	382	125
Total	299	227			738	3,961	1,682
Total after first spray	114	74					
			1951				
	May 4		May 5				
April 30–May 5	264	487	143	455	303	1,296	812
		May 9		May 8			
May 6–12	25	133	14	142	134	1,353	870
	May 14		May 15				
13–19	16	32	13	63	82	1,164	330
	May 25	May 21	May 25	May 21			
20–26	7	8	7	12	32	704	99
		May 30		May 30			
27–June 2	2	4	2	14	42	870	160
June 3– 9	3	2	11	6	36	414	124
10–16	4	3	4	3	28	122	200
17–23	12	27	9	65	122	1,552	564
24–30	10	26	16	37	135	1,807	636
July 1– 7	3	7	11	21	66	1,540	417
8–14	25	11	16	27	93	1,683	299
15–21	14	5	16	13	21	461	90
Total	385	745	262	858	1,094	12,966	4,601
Total after first spray	121	139	119	320			

May 25 and 30. Wettable sulfur was included in all spray treatments. Speed-type sprayers were used in all experimental orchards. The sprays were applied by cooperating growers in two orchards in 1950 and in three orchards in 1951. All the control orchards received applications of lead arsenate and sulfur at shuck split and 10 days later.

The comparative moth density in experimental and control orchards was measured by means of bait traps. The bait consisted of 10 per cent sugar (No. 10) solution in water and 0.5 ml. of a stock attractant solution (terpinyl acetate, extra grade, 97 parts and Tween 20, 3 parts) per quart of sugar solution (Chisholm *et al.* 1946). Traps consisted of paraffin-dipped

Table 2.—Infested peach twigs collected from 10 sample trees in orchards sprayed with parathion, EPN, or lead arsenate in 1950 and 1951.

	DATE OF SPRAYING AND NUMBER OF INFESTED TWIGS						
	Parathion			EPN		Lead Arsenate (control)	
	Orchard			Orchard		Orchard	
TWIGS COLLECTED	1	2	3	1	2	1	2
			1950				
	May 12	May 16	May 13				
May 16	0	0	0	—	—	0	0
22	0	0	0	—	—	2	0
	May 23	May 24	May 23				
26	0	0	0	—	—	0	0
31	0	0	0	—	—	11	5
	June 2	June 5	June 2				
June 6	0	0	0	—	—	96	37
9	0	0	0	—	—	104	28
14	0	0	0	—	—	72	35
20	0	0	0	—	—	48	23
23	3	0	0	—	—	24	8
28	0	0	0	—	—	22	4
July 3	0	3	0	—	—	26	28
7	0	11	7	—	—	51	45
14	11	20	4	—	—	179	211
20	8	29	8	—	—	195	157
Total	22	63	19			830	581
			1951				
	May 7	May 4	May 9	May 5	May 8		
May 10	0	0	0	0	0	0	0
		May 14		May 15			
14–15	0	1	0	0	4	16	30
	May 17						
16–18	0	0	1	0	0	34	120
			May 21		May 21		
21–22	0	3	0	1	5	54	157
	May 26	May 25		May 25			
28–29	0	1	0	0	0	59	83
			May 30		May 30		
31–June 1	0	0	0	1	0	19	66
June 4– 5	0	0	1	0	0	14	38
11–12	0	0	0	0	0	11	22
18–19	0	2	0	3	0	16	7
25–26	0	3	0	3	1	54	64
July 2– 3	10	5	4	8	29	163	376
11–12	25	10	8	1	19	149	218
16–17	14	6	0	0	1	33	64
Total	49	31	14	17	59	622	1,245

1-quart ice cream cartons covered by 4-mesh hardware cloth and equipped with a bail for hanging on branches near the top of trees.

MOTH DENSITY.—The overwintering- and first-brood moth density in orchards sprayed with parathion, EPN, and lead arsenate (control) was indicated by the number of moths caught in the bait traps. Six traps were placed in alternate trees in one row in each orchard. Baits were renewed in the traps at 2-week intervals, and old and new bait was provided by renewing the bait in alternate traps each week. Traps were not placed in the third orchard sprayed with parathion in 1950 and 1951 owing to their proximity to orchards sprayed with lead arsenate from which a large number of moths might have been attracted. Traps were placed in the orchards about May 1, at least a week before the first spray was applied for plum

Table 3.—Per cent of peach fruits infested near harvest in orchards sprayed with parathion, EPN, and lead arsenate in 1950 and 1951.

TREATMENT	ORCHARD NO.	VARIETY	DATE SAMPLED (August)	FRUITS INFESTED
Experiments in 1950				
Parathion	1	Elberta	23	2.0
	2	Elberta	23	7.5
	3	Summercrest	23	3.5
Average				4.3
Lead arsenate (control)	1	Summercrest	18	27.5
	2	Elberta	21	17.0
	3	Summercrest	19	45.5
	4	Summercrest	18	5.0
	5	Summercrest	21	34.5
	6	Elberta	23	12.5
Average				23.7
Experiments in 1951				
Parathion	1	Elberta	22	9.3
	2	Elberta	23	4.8
	3	Summercrest	20	11.0
Average				8.4
EPN	1	Elberta	22	2.0
	2	Summercrest	20	6.5
Average				4.3
Lead arsenate (control)	1	Summercrest	16	4.0
	2	Summercrest	16	70.5
	3	Summercrest	13	31.5
	4	Elberta	21	11.3
	5	Summercrest	16	12.5
	6	Afterglow	23	8.5
Average				23.1

curculio, and were examined each Monday, Wednesday, and Friday until the latter part of July. The number of moths caught during each week in 1950 and 1951 is shown in table 1.

Moths were abundant in orchards before the first application of insecticide. The results show that the parathion and EPN sprays killed almost all the moths in the orchards and that the population remained at a low level throughout the trapping period. Although EPN was tested for only 1 year, the results indicate that it is as effective as parathion in causing a reduction in moth population.

Since no insecticidal sprays were applied in the experimental orchards after the first few days of June, the moth population would be expected to be increased by migrant moths during the period of about 2.5 months between the last spray application and harvest of the peaches. Moths of the overwintering brood are present in orchards near Moorestown up to about June 20. Between June 20 and July 20 first-brood moths predominate. If first-brood moths migrated into the experimental orchards to any great extent, the number caught after June 20 would be considerably greater than the number of overwintering-brood moths caught between the time of the first spray application and June 20.

In 1950 and 1951 the migration of moths was determined from the following numbers that were caught in the orchards before and after June 20:

	Before June 20	*After June 20*
1950		
Parathion	93	95
Lead arsenate (control)	1,235	4,685
1951		
Parathion	146	114
EPN	258	181
Lead arsenate (control)	8,011	8,239

With the exception of the control orchards in 1950, there was no marked difference in the number caught in the experimental and control orchards before and after June 20. These data showed no evidence of moths migrating into the experimental orchards.

LARVAL POPULATION IN TWIGS.—From the middle of May to the latter part of July succulent twigs are usually abundant in bearing orchards near Moorestown. During this period most of the larvae feed in twigs in preference to fruit. An estimate of the larval population was obtained by collecting infested twigs each week from mid-May to mid-July from 10 previously designated sample trees located along the periphery of each experimental and control orchard. The number of twigs collected in the experimental orchards would indicate the population of larvae that were not killed by the insecticides in May and early in June and the progeny of the moths in the orchards thereafter.

The larval population (Table 2) was low in the orchards sprayed with parathion and EPN. Since moths were caught in these orchards in May after the first sprays were applied and in June after the last sprays (Table 1), the scarcity of infested twigs during this period indicates that due to the insecticides either few eggs were deposited by the moths, few eggs hatched, or that few larvae survived the exposure to the insecticides in crawling from the eggs to the twig terminals.

At summer temperatures about 7 to 10 days elapse between the time that an egg is laid until the feeding of the larva in a twig is evidenced by wilting leaves. Since first-brood moths usually start emerging in orchards near Moorestown about June

20, their progeny become apparent early in July. In 1950 approximately 30 times as many twigs were collected in the parathion-sprayed orchards in July as in May and June, while approximately twice as many were collected in the control orchards in July as in May and June. In 1951 about 7 times as many were collected in the parathion-sprayed orchards and about 3 times as many in the EPN-sprayed orchards in July as in May and June, while in the control orchards approximately the same number was collected in July as in the previous 2 months. Since the ratio of increase of infested twigs between May and June, and July was much greater in the experimental than in the control orchards, it is concluded that the increase in the former resulted from migrating first-brood moths. Although some migration was indicated, the number entering the experimental orchards must have been relatively small and of little significance, since the twigs collected in July in the experimental and control orchards averaged, respectively, about 3 and 45 per tree in 1950, and 3 and 50 per tree in 1951.

RIPE-FRUIT INFESTATION.—The larval injury in ripe Summercrest or Elberta fruits was determined from samples of 400 fruits from each sprayed orchard. Samples were obtained by taking 1 fruit at random from each tree passed as the blocks of trees were crossed several times in different directions. Each fruit was dissected and examined for larvae or signs of larval feeding. The degree of ripe-fruit injury observed in the orchards is shown in table 3.

The oriental fruit moth population was greatly reduced in orchards sprayed with parathion and EPN and remained low thereafter through the first half of August. The injury observed in some orchards indicated no need for preharvest applications of in ecticides to protect fruit. In the experimental orchards in which ripe-fruit infestations were 7.5, 9.3, and 11.0 per cent, an application of parathion, DDT, or EPN about July 31 would have been desirable. Since the degree of injury at harvest can not be anticipated, it is apparent that growers who use the parathion or EPN spray schedule for plum curculio control should apply these insecticides or DDT to Summercrest and Elberta, or varieties that ripen at about the same time as these varieties, about 3 weeks before harvest as a precautionary measure against oriental fruit moth injury in ripe fruit.

SUMMARY.—A study was made in 1950 and 1951 of the oriental fruit moth, *Grapholitha molesta* (Busck), adult density, larval population in twigs, and injury in ripe fruit in peach orchards near Moorestown, N. J., in which parathion and EPN spray schedules were applied to control the plum curculio, *Conotrachelus nenuphar* (Hbst.). Sprays were applied at shuck split and approximately 10 and 20 days later. After the first application approximately 97 per cent less moths were caught in bait traps in parathion-sprayed orchards and 96 per cent less in EPN-sprayed orchards than were caught in orchards treated with lead arsenate. The larva-infested twigs collected from sample trees averaged 3.3, 3.8, and 80.2, respectively, in 6 orchards sprayed with parathion, 2 sprayed with EPN, and 4 sprayed with lead arsenate (control). There was evidence that first-brood moths migrated into the experimental orchards, but the number was not sufficient to increase greatly the larval population in twigs.

Oriental fruit moth injury in fruit at harvest was determined on the varieties Summercrest and Elberta. Although no insecticides were applied between early June and harvest, a period of about 2.5 months, ripe-fruit injury averaged 4.3 and 23.7 per cent, respectively, in orchards treated with parathion and lead arsenate in 1950, and 8.4, 4.3, and 23.1 per cent, respectively, in orchards receiving parathion, EPN, and lead arsenate in 1951.

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SCIENTIFIC NOTES

Laboratory Colonization of *Aëdes triseriatus*

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During the spring of 1950 the transmission of various avian plasmodia by available species of anopheline and culicine mosquitoes was under study at the Emory University Field Station, Baker County, Georgia. Among the several culicine species utilized was *Aëdes triseriatus*. Since the supply of *triseriatus* larvae, collected in the field, was not constant enough to insure an adequate number of adults when desired, the need for a laboratory reared colony was recognized. To the writer's knowledge, there has been no report in the literature of successful colonization of this species.

Little difficulty had been experienced in rearing to adulthood the larvae which were collected from tree holes in the area. The larvae were brought to the laboratory in the water that had collected in the tree holes and were reared in this same water. Powdered dog biscuit was sprinkled daily on the surface of the water for food, and the surface kept clean of any harmful scum formation by dragging strips of paper toweling across it as needed. Several attempts were made to rear the larvae in tap water, but mortality was a great deal higher than when tree hole water was used. It should be mentioned that the water supply for this Georgia station is from a deep well and has no chemicals added to it.

The adults reared in the laboratory from field-collected larvae were kept in a screened, sleeve-front cage 2 by 2 by 3 inches which was housed in a room with controlled temperature and humidity of 77° to 79° F. and 75 to 80 per cent, respectively. When the attempts toward colonization were started, some difficulty was experienced in obtaining mosquito feedings when using rabbits and chickens, but a human host proved very successful. Human blood feedings were offered the adults daily, and some females fed when 2 days old; however, the majority fed 4 or more days after emergence.

In order to simulate, as nearly as possible, a natural oviposition surface, wooden bowls about the size and shape of standard finger bowls were fashioned from blocks of pine and blocks of cypress wood. Approximately 4 days after a majority of females had fed, these bowls were half-filled with tap water and placed in the cages overnight. Eggs were laid slightly above the water line in both bowls, with no apparent preference shown for either type of wood. These bowls were removed from the cages on the day following oviposition, and the water allowed to evaporate. As the bowls dried, large cracks appeared which of course rendered them unfit for further use. After the eggs and bowls had dried thoroughly, they were submerged in tap water for several days, but none of the eggs hatched. A few of these eggs were examined under the microscope, but were so desiccated that no evidence of viability could be found.

Small chips or blocks of hard wood next were tried as an oviposition surface. Several blocks of dried oak 1.5 by 1.5 by 3 inches were placed horizontally in a white enamel pan and tap water added to a depth of about one-half inch. This pan was introduced into the cage overnight and eggs were again obtained, being laid just above the water line. These blocks were kept in the pan, and the same water level maintained for approximately 2 days. The water was then drained off and the blocks allowed to dry; this drying was fairly gradual, since the oak blocks were well-soaked by the time the water was removed.

After thoroughly drying for a period of several days, the blocks were submerged in tap water and within 12 hours an excellent hatch was obtained. These larvae were reared in tap water, with daily feedings of pulverized dog biscuit. The mortality was negligible.

The laboratory-reared adults were large and vigorous, and after the females were approximately 4 or 5 days old no difficulty was experienced in obtaining blood feedings from laboratory animals. No records were kept on the generations produced in this colony, since the sole purpose was to provide uninfected females for avian malaria studies. It is estimated that at least six complete generations were reared prior to discontinuance of the colony.

No tests were conducted concerning the viability of *Aëdes triseriatus* eggs which were allowed to dry for any extended period. However, one block was submerged when slightly over 6 weeks old, and an excellent hatch resulted in approximately 15 hours. It is the author's belief that eggs of *triseriatus* obtained in this manner could be stored for an extended period, in much the same manner that eggs of *Aëdes aegypti* are commonly stored.

Orchard Mites Resistant to Parathion in Washington

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The development of resistance to some of the organic insecticides by certain insects is well known. In 1948 strains of the two-spotted spider mite (*Tetranychus bimaculatus* Harvey) resistant to aerosols of parathion were found in greenhouses in New Jersey and Connecticut (Smith & Fulton 1951). O'Neill & Hantsbarger (1951) found in apple orchards in the Wenatchee Valley of Washington in 1950 a strain of the European red mite, *Metatetranychus ulmi* (Koch), that was resistant to several organic phosphorus compounds. In 1951 strains of two species of resistant mites appeared in apple orchards in the Yakima Valley of Washington, affording an opportunity of making a preliminary study of them.

The possibility that resistant strains of mites existed was first reported by an apple grower who has a reputation for being very thorough in controlling pests and who had had no previous difficulty in controlling mites. He had been spraying his orchard with an air-blast machine, using about 1000 gallons per acre. The first application had been made about May 10 with 50 per cent DDT at the rate of 2 pounds and 25 per cent parathion at the rate of 8 ounces per 100 gallons. This treatment was repeated about June 11. After this application it became apparent that the treatments were not controlling an infestation of the European red mite, and

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Table 1.—Control of parathion-resistant European red mites with various acaricides, Wapato, Wash. (Treatment made on June 28.)

ACARICIDE (pounds per 100 gal.)	COUNTS PER 100 LEAVES ON—					
	July 2		July 13		July 30	
	Eggs	Mites	Eggs	Mites	Eggs	Mites
Aramite (15%) 1	2490	110	230	80	110	130
EPN (27%) 1	1610	130	330	190	190	110
p-Chlorophenyl *p*-chlorobenzene-sulfonate (50%) 1	420	100	140	0	30	0
R-242 (40%) 2	2100	90	510	140	320	60
Check (untreated)	—	—	3860	2340	[1]	[1]

[1] Sprayed with EPN about July 15.

he sprayed the orchard for the third time about June 19, omitting the DDT and increasing the parathion to 12 ounces per 100 gallons. Even this treatment failed to effect control and the situation was called to our attention.

A standard count was made on June 29 on 10 leaves taken at random from each of several trees. Considerable foliage injury from mites was evident and the count showed 3680 eggs and 1360 mites per 100 leaves. Since one would expect to find almost no mites or eggs after three applications of parathion, it was concluded that these mites had become resistant to it. Even a single application usually results in very effective control. For example, in one of our experimental plots in another orchard there were 3350 eggs and 513 mites per 100 leaves on June 25, previous to the application of any acaricide. On June 26 the trees were sprayed with 15 per cent parathion at 0.75 pound to 100 gallons. On July 12 the count showed only 7 eggs and 54 mites per 100 leaves.

On June 28 tests of four acaricides (Table 1) were made by the grower on a few trees, and counts taken at intervals thereafter showed that all of them controlled the resistant mites very well, *p*-chlorophenyl *p*-chlorobenzene-sulfonate[1] being the best.

Because it was available, the grower sprayed the the orchard with EPN at 0.66 lb. to 100 gallons to control this mite. Counts were made in two areas as follows:

DATE SPRAYED	JULY 13		JULY 20		JULY 30	
	Eggs	Mites	Eggs	Mites	Eggs	Mites
July 9	360	190	30	30	10	0
July 16	3860	2340	176	96	80	0

[1] Ovotran.

It is evident that in this orchard EPN effectively controlled the resistant European red mites, and no further infestation developed in 1951.

Late in July another infestation of mites developed in this orchard. The grower, thinking it was the Pacific mite (*Tetranychus pacificus* McG.) or the two-spotted spider mite, sprayed the orchard about July 25 with 25 per cent parathion at 12 ounces per 100 gallons. On July 30 counts made in various parts of the orchard showed from 2 to 6 mites and from 1 to 16 eggs per leaf. The mite was a species of *Tetranychus*. On August 7 another examination showed a rather alarming condition in some parts of the orchard. There was a population in one area as high as 13,240 eggs and 18,200 mites per 100 leaves, one of the highest populations we have ever recorded. It was evident that these mites were also resistant to parathion.

Several acaricides were applied on this mite on August 3 (table 2), and counts taken at intervals thereafter showed that all controlled the mites very well. Again because it was available, the grower used Aramite at 1.5 pounds to 100 gallons and had no further trouble with mites. However, because the presence of resistant mites had not been suspected, this orchard was sprayed with acaricides six times in 1951, although normally three applications would be enough. These six applications were as follows: May 10, June 11 and June 19, parathion; early July, EPN; July 25, parathion; and early August, Aramite.

Resistant strains of mites also appeared in several other orchards in the Yakima Valley in 1951. Two of these orchards were examined early in July, and a species of *Tetranychus* was found to be very numer-

Table 2.—Control of parathion-resistant mites with various acaricides, Wapato, Wash. (Treatment made on August 3.)

ACARICIDE (quantity per 100 gal.)	COUNTS PER 100 LEAVES ON—					
	August 8		August 15		August 21	
	Eggs	Mites	Eggs	Mites	Eggs	Mites
Aramite (15%) 1.5 lb.	530	0	40	20	0	0
DMC (25%) 1 pt.	0	0	0	0	0	0
Malathon (50%) 0.5 pt.	30	0	0	10	0	0
Check (untreated)	13,240	18,200	9,206	3,696	[1]	[1]

[1] Sprayed with *Aramite* on August 16.

ous. One orchard had been sprayed twice with an air-blast sprayer with 25 per cent parathion at 1 pound to 100 gallons. A count showed 6400 eggs and 7000 mites per 100 leaves. The other orchard had also been sprayed twice with an air-blast sprayer, but with 25 per cent parathion at only 8 ounces to 100 gallons. The count here was 9460 eggs and 8400 mites per 100 leaves. The latter orchard was then sprayed about July 10 with Aramite at 24 ounces to 100 gallons. Counts made on July 17 showed only 20 eggs and 170 mites per 100 leaves, and on August 8 no eggs or live mites could be found.

Specimens of this second species were sent to E. W. Baker, U. S. National Museum, who at first considered them to be *Tetranychus mcdanieli* McG. Later examination of a larger series indicated that *mcdanieli* may be a subspecies or variant of *T. pacificus* (Pritchard and Baker 1952). If this mite turns out to be *pacificus*, a parathion-resistant strain of *pacificus* has developed in the Pacific Northwest. On the other hand, if the species is finally determined to be *mcdanieli*, then it is more difficult to control with parathion than are some of the other species of orchard mites.

SUMMARY.—A strain of the European red mite (*Metatetranychus ulmi* (Koch)) resistant to parathion, and possibly to other organic phosphorus compounds, exists in apple orchards in the Pacific Northwest. There is also in these orchards a species of *Tetranychus* that resists parathion. It is either a resistant strain of *pacificus* or a distinct species, *mcdanieli*. Preliminary tests indicate that these mites may be controlled, at least temporarily, with a number of acaricides, including Aramite, DMC, EPN, malathon, *p*-chlorophenyl *p*-chlorobenzenesulfonate, and R-242.

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A Parasite of the European Elm Scale Established in California

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In North America the control of the European elm scale, *Gossyparia spuria* (Modeer), by biological means has been awaiting solution for many years. Although this insect has seriously infested one of the most popular of ornamental shade trees, there have been few attempts to introduce and establish the natural enemies of the pest. This in spite of the well-known fact that the elm scale in Europe is under excellent natural control.

In 1908 George Compere collected parasitized elm scale in Germany and sent it to California where the scale has existed since 1893. There is no record, however, of parasites having been released. If releases were made none became established.

In 1939 parasitized elm scale collected in Italy was sent to California by Harry S. Smith. The aphelinid *Coccophagus insidiator* (Dalman) and the encyrtid *Trichomathus cyanifrons* (Dalman) were reared from this material. The material received however was sufficient for only a single release of 50 females of *C. insidiator*. This was made at Los Gatos, California. Establishment did not take place. This may be accounted for by the fact that a large number of the females were not mated.

During the years 1948 to 1950 inclusive, the U. S. Bureau of Entomology and Plant Quarantine cooperated with the Department of Biological Control of the University of California Agricultural Experiment Station in collecting elm twigs infested with European elm scale in France and Germany, and sending them to Riverside. The parasites obtained from the 1948 shipment were inadequate for release. The 1949 shipments, however, yielded 326 females and 17 males of *Coccophagus insidiator* and a dozen specimens of *Trichomathus cyanifrons*. The latter, which is gregarious in development, was propagated in the laboratory for one generation.

PARASITE RELEASES.—Mated females of *Trichomathis cyanifrons* released in June, 1949 comprised 27 in Redlands, 13 near Balboa, and 16 in Pasadena. *T. cyanifrons* reproduced for one generation at Redlands and then died out. No other recoveries of this species have been made.

Mated females of *Coccophagus insidiator* released in May and June 1949 comprised 175 in Redlands, 80 near San Jose, and 65 near San Anselmo.

The 1950 shipments yielded 139 females and 21 males of *Coccophagus insidiator* and eight specimens of a *Microterys* sp. In May and June 61 mated females of *C. insidiator* were released in San Anselmo and 78 in Berkeley.

The *Microterys* sp. was propagated for one generation. The progeny consisted only of males. No releases were made.

Establishment of *Coccophagus insidiator* is known only in Redlands where the releases were made on two large elms in the dooryard of a residence. Twenty-five females were released on May 10, 25 on May 12, and 125 on May 20.

The release trees in 1949 were the only trees in the area having scale infestation suitable for establishment of the parasites. Other trees in the area either had not become infested, had only incipient infestations, or had been sprayed. The Agricultural Commissioner of San Bernardino County cooperated in the finding of scale infestations suitable for parasite releases.

Within three years after the first parasite release had been made in Redlands, the elm scale had spread to neighboring dooryard trees. The parasite, following its host, also spread from the point of original establishment.

Coccophagus insidiator was originally recovered from the release trees in July 1951. At that time the trees were practically free of scale and had improved greatly in appearance. The following year (1952) the infestation was noticeably greater, but not causing serious injury to the trees. By June, however, the percentage of parasitization of mature female scales on these trees was 85 per cent. The natural spread of parasites has included infestations about 100 yards southeast and northeast of the release trees.

Collections of parasitized elm scale from the release trees show that *Coccophagus insidiator* has three and possibly five generations to one of its host, the host having one generation annually. These generations occur as follows: one generation on the

[1] Professor of Biological Control and Entomologist in the Experiment Station.

overwintering prepupal male, one on the nongravid female and one to three on the gravid female.

Coccophagus insidiator is solitary in development, the female being an endoparasite of the elm scale, the male an ectoparasite of its sister female. The external hyperparasitic relation of the male is assumed because of the fact that the first instar larvae possesses four pairs of abdominal spiracles. Unmated as well as mated females oviposit readily in the body cavity of the elm scale. Presumably the male egg does not hatch until the female has consumed the body contents of the host.

The life cycles of the three introduced parasites of European elm scale at 80° F. are as follows:

Coccophagus insidiator, 22 days,
Microterys sp., 17 days,
Trichomathus cyanifrons, 15 days

The identifications of these species were made by Harold Compere. The U. S. Bureau of Entomology and Plant Quarantine in 1951 and 1952 continued the shipment of parasitized European elm scale to California. This material was processed in the Albany Quarantine Laboratory of the Department of Biological Control by R. L. Doutt and the releases in northern California during those years have been made under his direction.

An Unusual Infestation of Wood Cockroaches

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The Pennsylvania Wood-Roach, *Parcoblatta pennsylvanica* (DeGeer) is a common cockroach in southeastern South Dakota. It is usually found underneath loose bark of trees, stumps, or logs. Occasionally it has been reported as a household pest, especially country houses in wooded areas. In such houses this roach behaves like most of our other roaches that invade houses, stores, restaurants, etc. and it feeds on foods that are available. However, the wood-roaches also eat paper and, at times, they have been destructive to wall paper.

In July 1951 an infestation of wood-roaches was discovered in the county jail of Hughes County, Pierre, South Dakota. The jail is located on the top or fourth floor of the county court house. The court house is constructed of brick and stone. Only the top floor of the building was infested with the wood-roach. Not only were the living rooms and cells infested, but the flat roof of an open veranda was also infested. On the floor of the veranda, were found pieces of lumber, crates, and boxes. Under all of these, specimens of adult and nymphal wood-roaches were found in considerable numbers. Inside of the corridors and halls, adult and nymphal cockroaches of this species were also found rather plentifully. To attempt an explanation as to how the cockroaches originally found their way to the top floor of this court house would lead one to interesting speculation. The male wood-roaches are fully-winged and are excellent fliers. The females are nearly all short-winged, but occasionally one runs across a specimen that has fairly long wings. However, it is doubtful that even such long-winged females can fly. If it be true that none of the females can fly, then the infestation originated either by the females crawling up the side of the building to the veranda (which does not seem likely) or the cockroach was transported in some way to the site of the infestation. This last explanation seems to be the most plausible, for it is not uncommon to introduce other species of cockroaches into a home or other buildings by bringing into it boxes or crates or bags or packages of food, laundry, fruit, etc. that happen to be infested with cockroaches.

It should be stated that on the open veranda of this courthouse, a 60 watt electric lamp was kept lighted every night from sundown to dawn. A thorough examination of the trees on the lawn of the court house did not reveal a single wood-roach, but in the bottom lands of the Missouri River, about one-half mile distant, the wood cockroach was common.

The Leaf Roller Moth *Pandemis pyrusana*

E. J. NEWCOMER and F. W. CARLSON, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[1]

The leaf roller moth, *Pandemis pyrusana* Kearf., has been causing injury to cherries and apricots in the Pacific Northwest during the last few years. The first published record of this insect as a fruit pest apparently came from California, where Penny (1921) found it injuring apples in the Watsonville district. Essig (1926) called it the apple pandemis, and said the caterpillars "feed on the leaves and fruit of apple in California." The senior author reared a moth of this species from a larva on apple at Wenatchee, Wash., in August 1916, and another at Ellensburg, Wash., in July 1922. A moth was taken in a bait at Yakima, Wash., in August 1921. However, there was no evidence of any serious injury from this species in Washington until 1948.

At the end of June 1948, cherry growers in the Yakima Valley reported finding numerous small, whitish lepidopterous larvae in lug boxes of harvested cherries. Such cherries were being refused by fruit buyers because of the infestation. In some instances these larvae were being confused with maggots of the cherry fruit fly, *Rhagoletis cingulata* (Loew). Moths were reared from some of the larvae and found to be *Pandemis pyrusana*. In July and August reports began coming in of injury to apricots and plums by larger, greenish larvae, and again they were found to be *Pandemis*.

Injury to cherries has been rather sporadic but is often serious when it occurs. The percentage of cherries injured is rather small, the chief loss occurring because cherries have been refused by buyers. We have had reports of considerable tonnages being turned down, although the presence of the cherry fruit fly and the confusion of the two pests by fruit buyers make it difficult to tell how much loss was actually due to *Pandemis*. It is serious enough to cause growers to ask for control measures.

In apricots the injury is also sporadic. We have seen a number of crops in which it was serious enough to cause the grower much concern. In one such instance the fruit in 10 lug boxes, chosen at random from the harvested crop, was examined. Of the total of 4282 apricots, 469, or 11 per cent, were injured, and about 2 per cent of this fruit had worms still in it when examined.

HABITS.—On cherries, the *Pandemis* larvae at

[1] Some of the observations in 1948 were made by M. A. Yothers, formerly of this Bureau.

first feed on the foliage under some webbing spun along a midrib, and later they usually tie two leaves together or roll the edge of a leaf over and tie it down for protection. They also feed on the fruit, the small larvae spinning some webbing about the stem and eating into the cherry beneath it. Occasionally a larva will burrow into the cherry along the pit.

On apricots, feeding on the leaves is similar to that on cherries, but often a leaf is tied to the side of a fruit and both leaf and fruit are eaten into. The larger larvae commonly seek the protection of a cluster of apricots, spinning some webbing between the fruits and eating holes in all fruits in the cluster. The holes may be a half inch or more in diameter, and the larvae feed rather freely about the pits. Little damage has been seen on any other kind of fruit.

LIFE HISTORY.—Partly grown larvae, about 0.37 inch long, go through the winter at the bases of the trees, or in protected places in the rough bark on the trunks or lower limbs. Feeding starts as soon as there is new foliage, usually by late April. Pupation occurs early in June, most often in the rolled-up leaves, and moths emerge soon after, being most numerous about the middle of the month. Eggs are deposited in flat masses on the leaves and hatch during the latter half of June. Larvae from these eggs develop rather slowly, small larvae collected on June 30 did not produce moths until after the middle of August. Moths of this second brood have been taken most commonly in baits from late August until the end of September. Larvae appear late in September and go into hibernation in October. There are thus two broods a year.

Two parasites have been reared from the larvae—an ichneumonid, *Horogenes* sp.,[2] and a larvaevorid, *Nemorilla floralis* (Fall.).[3] Parasitism is not common

RELATED SPECIES.—Another species of leaf roller that may be confused with the fruit tree pandemis moth is *Amelia pallorana* (Rob.). This species has been reported during the last 25 years in the East and Middle West as a pest of such different plants as roses, strawberries, alfalfa, and pines. The most recent report, by Snow and McClellan (1951), was concerned with its infestation of seed alfalfa in Utah. It has been very common in the Yakima Valley for the last three seasons, larvae having been found on apple, cherry, and pear, but more often on shrubby and succulent plants, including alfalfa, asparagus, sweetclover, dock, goldenrod, lambsquarters, milkweed, mullein, sumac, sycamore, Canada thistle, and willow. It has not been a serious fruit pest, except occasionally in young apple orchards, where it has partially defoliated the trees.

DISTINGUISHING CHARACTERISTICS.—The two species are easily distinguished. The eggs of both are laid in clusters on the leaves, *Pandemis* eggs being greenish and overlapping in the cluster, those of *Amelia* yellowish and not overlapping. The larvae of both are very active, wriggling about, when disturbed, in characteristic leaf roller fashion. *Amelia* larvae are greener and lighter colored than *Pandemis* larvae, especially after preservation in alcohol, and the last segment of the abdomen, when viewed from above, is rather pointed, while in *Pandemis* it is more rounded. Both larvae can be told from those of the oblique-banded leaf roller, *Archips rosaceana* (Harr.), or the fruit tree leaf roller, *Archips argyrospila* (Wlkr.), by their green heads, the larvae of the latter species having dark-brown heads. The pupae of *Amelia* are blackish, with lighter areas on the abdomen, those of *Pandemis* are brown.

Table 1.—Tests of insecticides for controlling the fruit tree pandemis moth on two cherry trees, 1949.

INSECTICIDES	PER CENT ALIVE	PER CENT DEAD	PER CENT MISSING
Dusts:			
DDT (10%)		10	90
Parathion (2%)		40	60
Sprays (quantity per 100 gal.):			
Parathion (15%)			
1 lb.	5	40	55
2 lb.	5	25	70
TEPP (20%) 1 pt.	20	40	40
Check	66		34

The moths of *Amelia pallorana*, as the name suggests, are cream-colored or light tan, without markings. *Pandemis* moths are buff-colored with a darker marking on the anterior margin of the fore wing near the tip, an oblique dark band across the middle of the wing, and a finer network of dark lines covering the wing. The markings are so nearly like those of the oblique-banded leaf roller that the species can best be distinguished by the genitalia, although the male of *Pandemis* has a notch on the dorsal side of the second antennal segment which *Archips* does not have.

Pandemis moths come into baits freely those of *Amelia* do not. Both species are attracted to lights, and *Amelia* is often particularly numerous about the neon lights of advertising signs.

CONTROL.—Since the fruit tree pandemis moth is not easily controlled with lead arsenate, a number of other insecticides were tested. In April 1949 two cherry trees were treated with each of several insecticides, 20 rolled-up leaves containing worms having previously been tagged on the trees. The results are given in table 1.

Evidently the DDT dust drove many of the larvae out of the leaves.

In April 1951 another test was made in a heavily infested apricot orchard, with the results shown in table 2.

These tests indicate that good control of the fruit tree pandemis moth can be obtained with any of the

[2] Determination by B. D. Burks, Division of Insect Detection and Identification.

[3] Determination by C. W. Sabrosky, Division of Insect Detection and Identification.

Table 2.—Tests of insecticides for controlling the fruit tree pandemis moth in an apricot orchard, 1951.

INSECTICIDE (quantity per 100 gal.)	NUMBER OF LARVAE BEFORE SPRAYING	PER CENT REDUCTION
DDT (50%) 2 lb.	71	96
Parathion (25%) 1 lb.	39	100
TEPP (20%) 1 pt.	54	96
EPN (27%) 8 oz.	42	90
TDE (50%) 2 lb.	30	100
Check	13	0

insecticides tried. TEPP has been particularly useful when an infestation is discovered in a cherry crop at harvest. It can be used safely one or two days before picking. Some control of overwintering larvae can be obtained by dusting the tree trunks with DDT in the spring before migration takes place. Spraying should be done as soon as the blossoms have dropped when the danger of poisoning bees is past.

SUMMARY.—The fruit tree pandemis moth, *Pandemis pyrusana* Kearf, has been a pest of cherries and apricots in the Pacific Northwest since 1948. It has two broods a year, the spring brood of larvae feeding on the foliage and the summer brood feeding on both fruit and foliage. Small larvae in cherries are sometimes mistaken for those of the cherry fruit fly by fruit buyers. Pandemis moths look very much like those of the oblique-banded leaf roller, but the larvae are easily distinguished. A related species *Amelia pallorana* (Rob.), may be mistaken for pandemis in the larval stage. Control may be effected by spraying or dusting with DDT, parathion, TEPP, or TDE in April or June.

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A Virus Disease of the Red-Banded Leaf Roller

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In August 1949 while rearing red-banded leaf roller larvae, *Argyrotaenia velutinana* (Walker) it was noticed that a few larvae differed in color from the normal green or yellow-green coloration, often becoming a pale yellow. As the season progressed, there was an increase in the number of affected larvae. The first definite indication of the disease was the appearance of two longitudinal white streaks on the dorsal side. The abnormal larvae fed at a reduced rate, ceased to develop and generally died before reaching maturity.

Specimens of diseased larvae were sent to Dr. E. A. Steinhaus, University of California, who identified it as a form of granulosis, a virus type disease. He further stated that this is the first recorded occurrence of any granulosis in insects in this country outside of California.

This year it has been observed that a larva which becomes infected while it is young, dies before pupation. If the larva is half grown or nearly full grown and becomes diseased, it will often pupate. Very small numbers of diseased larvae and pupae were under observation but approximately a third of them emerged as adults and deposited eggs.

To obtain insects for the life history study, eggs and adults were collected in the early season of 1949 in an orchard near Cloverdale, Virginia. The studies in 1950 were made with apparently healthy insects that had been saved from life history studies of the previous season. Briefly the life history study was made as follows: The moths were held in glass containers where they deposited eggs. On hatching, an individual larva was placed in a glass tube which contained a tender apple leaf, the stem of which was inserted in a bottle of water. A fresh leaf was supplied when needed. Thus there was no contact between the larvae after leaving the egg mass. In the insectary, during the season of 1950, 28 per cent of the first brood and 15 per cent of the second brood larvae were diseased. The disease progressed more rapidly in the third brood. For the life history study 189 larvae of the third brood were retained, of these 74 per cent exhibited the disease by October 4 and 97 per cent by October 18.

The question naturally was asked: Is the disease confined to the insects being studied in the insectary? To determine whether or not this was true, leaf roller larvae were collected during October 1950 in orchards in most of the apple sections in Virginia. In some orchards no larvae could be found, whereas in others the insect was present in small numbers, but always some of them were diseased.

Nothing is known as to how the larvae become infected or how long the disease has been present. It has been established that the granulosis disease is generally present and that the leaf roller population has already been greatly reduced.

Insects Observed at Sea

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While serving on board a United States Naval auxiliary type vessel operating in the Hampton Roads–Virginia Beach, Virginia area, the writer noticed large numbers of house-flies, *Musca domestica* Linné, appearing on the ship shortly after it anchored at 5.00 P.M. EDT on 12 August 1952. The anchorage was about 22 miles from the nearest land which was Virginia Beach, Virginia. During the day the ship operated in an area ranging from 20 to 40 miles from land.

The absence of flies was very noticeable during the daytime operations of 13 August. A thorough inspection of the ship failed to reveal the presence of any flies on board during the time the ship was underway. The ship was extremely clean and offered no place whatsoever from which flies may have been emerging. There were very few other ships operating in the immediate area. No strong offshore breezes were noticed.

Upon anchoring at 5 P.M. on 13 August the flies again appeared. By 6 P.M. enough flies were present to cause comment from the crew during the evening meal. However, the flies again disappeared on the morning of 14 August.

While taking a turn about the decks on the mornings of 13 and 14 August several *Diabrotica undecimpunctata howardi* Barb. adults were found. Also, two *Chrysopa sp?* adults were observed. Both species had settled on the ship some time during the night.

The appearance of insects without being in immediate contact with land, the distance to the nearest land, the absence of insects during under way hours and the absence of offshore breezes appears to substantiate the fact that some insects have much more flight stamina than has normally been accorded to them.

Resistance of European Red Mite to Parathion[1]

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A report was received by the writers in July of this year (1952) that a European red mite infestation in an orchard near New Paltz, New York, had apparently developed resistance to parathion. A test was initiated to obtain experimental evidence on whether or not this condition was true. Some parathion had been used in this planting since 1948. A detailed record of its use with the dosage given in pounds for 500 gallons of water follows: In 1948, 4 pounds (25 per cent) on August 2 and 2.5 pounds (25 per cent) on August 10; in 1949, 3 pounds (25 per cent) on July 13; in 1950, 3 pounds (15 per cent) on July 19; in 1951, 2.5 pounds (15 per cent) on June 28, July 10, a 1 per cent dust on August 10, and 3 pounds on August 15 and September 15; in 1952, 10 pounds (15 per cent) May 28, 10 pounds June 3, 8 pounds June 12, 2.5 pounds June 20, and TEPP (40 per cent) 1 quart on July 17.

Table 1.—Response of a European red mite population to parathion and other acaricides in the Ada M. Du Bois orchard, New Paltz, N. Y., 1952. Host: Golden Delicious apple.

Material and Rate per 100 Gallons		Per Cent Reduction in Population[1]		
		7/23	7/26	7/29
Treated July 22				
Parathion (15% w.p.)	½ lb.	—	25.2	—
	1 lb.	18.2	26.4	—
	2 lbs.	52.8	49.1	57.3
EPN (25% w.p.)[2]	½ lb.	76.4	98.3	—
Systox (42% emul.)[3]	4 ozs.	91.5	99.2	—
Aramite (15% w.p.)[4]	1½ lbs.	—	99.7	—
Treated July 25				
Parathion (15% w.p.)	2 lbs.	—	62.7	74.0
Malathon (25% w.p.)[5]	2 lbs.	—	72.3	54.3
		Average number mites per leaf		
Control:		41.6	41.9	15

[1] Records are based on 10-leaf samples individually collected and examined by six observers on July 23, by four on July 26, and three on July 29. Total leaves examined were: 480, 480, and 160, respectively.

[2] 0-ethyl 0-*p*-nitrophenyl benzenethiophosphate.

[3] 0-(2-(ethylmercapto)ethyl)0,0-diethyl thiophosphate.

[4] 2-(*p*-tertbutylphenoxy) isopropyl-1-methyl 2-chloroethyl sulfite.

[5] 0,0-dimethyl dithiophosphate of diethyl mercaptosuccinate.

The apple variety in the test block was Golden Delicious. The trees were of moderate size, and growth was open to the extent that no problem was presented in attaining adequate spray coverage. A Bean Speed Sprayer had been used by the grower to apply all spray treatments in the test block during the past 5 years.

When test sprays were applied on July 22, the trees bore a population of 41 hatched mites per leaf. These consisted almost exclusively of the European red mite, *Paratetranuchus pilosus* (C. & F.). Treatments were applied with a hydraulic sprayer operating under 600 pounds pressure. A single nozzle spray gun was used. An excessive gallonage was applied—30 to 40 gallons per tree—to insure complete coverage. The method of taking records is the same as that previously described by Chapman & Lienk (1950).

Table 2.—"Normal" response of non-resistant European red mite populations to parathion (wettable powder formulations) in acaricidal tests 1949–1952.

Toxicant Strength	Rate per 100 Gals.	Date of Treatment			Per Cent Reduction in Population	
					Days After Treatment	
		Year	Date	Max. Temp.	2–3	9–10
	oz.					
25%	4	1949	7/19	83	91.4	57.4
25%	8	1949	7/19	83	89.3	61.4
25%	16	1949	7/19	83	95.8	93.5
25%	4	1949	8/9	98	99.8	60.8
25%	8	1949	8/9	98	100.0	94.7
25%	16	1949	8/9	98	99.8	99.3
15%	16	1950	7/9	85	98.2	95.8
15%	16	1951	7/3	77	97.5	95.7
15%	16	1952	7/4	94	98.7	99.9

Materials tested and results obtained are given in table 1. It was not possible to carry out a duplicate experiment simultaneously in an orchard where the mites were surely known to be non-resistant. However, the performance of parathion to non-resistant red mites is well known and has been closely reproducible in earlier tests conducted by some of the authors (Lienk & Chapman). Results of some of these tests are given in Table 2. Attention is called particularly to the results obtained in 1952. This test was initiated two weeks earlier than the New Paltz experiment.

As will be seen in table 2 the acaricidal efficiency of parathion is apparently affected by the temperature prevailing at treatment time or possibly for that day and for one or more succeeding days. Better results have been obtained at the higher temperature. This point is mentioned because very warm weather occurred July 22, 23 and 24, a condition which from table 2 evidence should have been favorable for the action of parathion in the New Paltz experiment. Maximum temperatures for these days were: 98°, 97°, 85°, respectively.

The evidence given here shows that the mite population in the New Paltz orchard has developed resistance to parathion. While the evidence is not as clear cut, it appears that the population is likewise resistant to malathon. No resistance is evident to the other phosphorous acaricides tested, namely, EPN and Systox. The mites in this orchard proved highly susceptible to Aramite.

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Toxicity to the House Fly of Two Chlorinated Turpentines in Space Sprays

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Early in 1951 two commercially prepared compounds[1] were submitted to this Bureau for testing as possible insecticides. Both were chlorinated turpentines made with the use of a catalyst by liquid-phase chlorination of material from two sources of turpentine, one from sulfate wood, and the other from gum spirits. A study was made to evaluate their toxicity in comparison with toxaphene, a similar material.

MATERIALS AND METHODS.—The chlorinated sulfate-wood turpentine contained 63.0 per cent of chlorine; the chlorinated gum spirits of turpentine contained 60.3 per cent. The toxaphene was of technical grade containing 67.6 per cent of chlorine. Pyrethrins, 51.5 per cent of which was pyrethrin I and cinerin I, was also included in the study, since it is the usual standard of comparison in house fly tests.

The materials were dissolved in refined kerosene at such concentrations that the mortality results, as indicated by preliminary tests, extended over the 50 per cent mortality point.

The tests were made by the Campbell turntable method against house flies, *Musca domestica* L., reared by standard laboratory procedure. Knockdown and mortality were estimated from tests replicated five times with flies two to three days old. Approximately 100 flies were used in each test.

KNOCKDOWN AND MORTALITY RESULTS.—Knockdown of flies in 25 minutes was negligible for the chlorinated compounds. As usual, for pyrethrins knockdown was complete at the concentrations used. The mortality data are summarized in table 1.

EVALUATION OF RELATIVE TOXICITY.—Methods of probit analysis described by Finney (1947) were used to obtain regression lines from the mortality data and to estimate the LC-50 and its standard error for each of the compounds. The LC-50's and their errors are also given in table 1. Relative toxicity was calculated as the inverse ratios of the LC-50's. The equations for the chlorinated compounds were generalized. Pyrethrins was not included in the generalization, since its regression coefficient was found to be significantly different from the chlorinated compounds. The individual equation for pyrethrins and generalized equations for the chlorinated materials showing the relationship between the transformed functions of the variates, probits, and logarithms of concentrations in milligrams per centiliter are:

Pyrethrins	$Y=2.485\ X+1.834$
Chlorinated sulfate-wood turpentine	$Y=5.185\ X-4.180$
Chlorinated gum spirits of turpentine	$Y=5.185\ X-4.013$
Toxaphene	$Y=5.185\ X-0.138$

The individual regression coefficients for the chlorinated compounds were, respectively: 5.09, 5.25, and 5.22 probits per unit log concentration. Analysis of the data showed no significant deviation from parallelism, hence justifying the fitting of parallel lines as shown by the equations above. However, since heterogeneity between populations had increased residual heterogeneity, a factor (3.73) was used in estimating errors. For the pyrethrins, departure from linearity was not significant.

CONCLUSIONS.—Both chlorinated turpentines were found to be about one-sixth as toxic as toxaphene. Compared at the median lethal concentration, pyrethrins was half as toxic as toxaphene. These findings agree with the results of screening tests made with toxaphene by the same method in 1945 and 1948 (unpublished). On this basis the chlorinated turpentines are about one-third as toxic as pyrethrins.

Knockdown for the chlorinated compounds was inconsequential at the concentrations used.

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[1] Tennessee Products and Chemical Corporation, Nashville, Tenn.

Table 1.—Relative toxicity to house flies of the chlorinated turpentines and toxaphene.

MATERIAL	CONCENTRATION	MORTALITY IN 1 DAY	CONCENTRATION CAUSING 50 PER CENT MORTALITY	RELATIVE TOXICITY
	Mg. per ml.	*Per Cent*	*Mg. per ml.*	
Chlorinated sulfate—wood turpentine	10.0	87.6	5.86 ± .20	0.17
	6.75	61.7		
	4.5	27.6		
	3.0	9.1		
Chlorinated gum spirits of turpentine	10.0	92.1	5.47 ± .14	0.18
	6.75	67.2		
	4.5	32.2		
	3.0	9.2		
Toxaphene	2.0	95.7	0.979 ± .030	1.0
	1.33	75.7		
	0.889	36.8		
	0.593	15.7		
Pyrethrins	8.0	95.0	1.90 ± .06	0.52
	4.0	77.6		
	2.0	53.8		
	1.0	25.0		

Effects of Kernel Characteristics and Components of Husk Cover on Rice Weevil Damage to Corn[1]

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The relationship between husk cover of corn and rice weevil, *Sitophilus oryza* (L.), damage reported in a previous paper (Eden, 1952) prompted a study of some components of husk cover of corn and their effect on rice weevil damage. The results of this study and investigations of the effect of kernel characteristics on rice weevil damage are reported here.

COMPONENTS OF HUSK COVER.—The components studied were length of husk tip and the number of leaves per husk. The study was made just before harvest on corn from a field of U. S. 13 hybrid. Twenty ears of each of the 5 husk cover ratings reported previously (Eden 1952) were selected at random from the field. The length of the husk tip of each ear was measured, and the number of leaves in each husk was counted. The ears were shelled, and the weevil damage on each ear was determined by the acid fuchsin stain method (Frankenfeld 1948).

The results of the study are presented in table 1 and figure 1. The rice weevil damage decreased as the length of the husk tip increased. Also, the weevil damage decreased as the number of leaves per husk increased. Furthermore, as shown in figure 1, the effects of the two factors were independent of each other. At a constant length of husk tip, the weevil damage decreased as the number of leaves per husk increased. At a constant number of leaves per husk, the weevil damage decreased as the length of the husk tip increased. The husk cover which provided the greatest protection against weevils consisted of the combination of the greatest length of husk tip and the greatest number of leaves per husk.

KERNEL CHARACTERISTICS.—Two characteristics of the corn kernel were studied in relation to rice weevil damage at harvest. They were the hardness of the kernel and the thickness of the pericarp. Twenty varieties of corn were used. The husk cover ratings were made before the corn was harvested. The rice weevil damage was determined on the varieties at harvest. This provided a means of removing the effects of husk cover by multiple regression.

Hardness.—Shelled samples of the 20 varieties and hybrids of corn were adjusted to 12 per cent moisture and tested for hardness. A Link spring checker, Model PB8, was used for measuring the pressure in pounds per square inch required for penetration of the kernels with a 1/16-inch hollow, hard-steel punch. The kernels were placed on a wooden block on the spring checker anvil and punched on the side opposite the embryo. The pressures required for penetration were measured for 50 kernels of each variety. Only flat kernels were used.

The results of the study are presented in tables 2 and 3. As shown in table 2, the pressure required for penetration of the kernels varied from 59.60 pounds per square inch for North Carolina 1032 to 38.82 pounds for Dixie 17. In the multiple regression shown in table 3, where the effect of husk cover was removed, the regression coefficient for hardness, $b_{Y1.23}$, was −.9655, which was highly significant. This indicated that for each increase of one unit of hardness (pounds per square inch of pressure required for penetration) there was a decrease in weevil damage of almost one per cent.

Table 1.—Summarized data on components of husk cover and rice weevil damage.

HUSK COVER RATING	LENGTH OF HUSK TIP	LEAVES PER HUSK	RICE WEEVIL DAMAGE
	Inches	*No.*	*Per Cent*
5	2.82	10.29	6.56
4	2.59	10.06	17.83
3	2.08	9.32	36.10
2	1.59	9.18	55.66
1	0.70	8.82	69.51

It is interesting to note how much more significant the effect of husk cover was than that of hardness. The regression coefficient for husk cover, $b_{Y2.13}$, was −23.4974. This indicated that an increase of one unit of husk cover decreased rice weevil damage 23.5 per cent.

Thickness of the kernel pericarp.—A study was made to determine if there was any relationship between thickness of the pericarps of corn kernels and the amount of damage done by the rice weevil. Inasmuch as the female weevil chews a hole through the pericarp to implant her egg into the endosperm, it appeared that the thickness of the pericarp might be related to the amount of damage that a corn variety suffers from this insect.

The same 20 varieties were used in this study as in the investigations on hardness. The thicknesses of the pericarps of 100 kernels of each variety were measured after the samples were adjusted to 8 per cent moisture. The kernels were cut transversely into two halves with a sharp knife, and the upper halves of the kernels were placed for one-half minute in an aqueous solution of 20 per cent potassium iodide and 1 per cent iodine. The kernel halves were then removed from the solution and dried with a cloth. The starch of the kernels was dyed black,

[1] Part of the data presented herein were taken from a thesis presented to the graduate faculty of the University of Illinois in partial fulfillment of the requirements for the Ph.D. degree.

Table 2.—Rice weevil damage to corn as related to hardness, thickness of the pericarp, and husk cover.

VARIETY	WEEVIL DAMAGE	HARDNESS	THICKNESS OF PERICARP	HUSK COVER RATING
	Per Cent	*Lb./Sq. In.*	*Microns*	
North Carolina 1032	44.6	59.60	114.0	2.76
Funks G-717	44.9	54.52	114.9	3.09
McCurdy 1002	26.3	53.46	119.1	3.72
Funks G-714	46.3	51.96	97.8	3.48
Dixie 44	62.7	51.60	136.0	2.84
Dixie 18	44.6	51.26	95.8	4.67
P.A.G. 170	74.6	50.22	118.5	1.93
P.A.G. 630	68.5	49.82	102.9	3.14
North Carolina 26	37.1	49.38	102.5	3.43
Louisiana 521	27.0	48.76	95.6	3.91
Louisiana 1031	30.1	46.96	107.5	3.94
U.S. 13	87.1	46.88	118.4	1.81
North Carolina 27	32.9	46.34	120.0	3.75
Woods S-360	41.9	45.42	95.3	3.87
Mosby	43.2	43.98	97.1	3.20
Tennessee 10	53.9	42.62	105.4	3.43
Dixie 11	28.5	41.38	92.1	4.06
McCurdy 1005	57.9	40.54	106.3	3.17
Paymaster	61.7	39.90	115.2	3.45
Dixie 17	56.2	38.82	107.3	3.17

Table 3.—Pertinent data from multiple regression of rice weevil damage on hardness, husk cover, and thickness of pericarp of corn.

VARIATE	PARTIAL REGRESSION COEFFICIENT	VALUE OF (b) IN % WEEVIL DAMAGE	STANDARD PARTIAL REGRESSION COEFFICIENT	VALUES OF b-PRIMES	t FOUND	TABULAR t .05	TABULAR t .01
Hardness	$b_{Y1.23}$	−.9655	$b'_{Y1.23}$	−.2929	3.362	2.160	3.012
Husk Cover	$b_{Y2.13}$	−23.4974	$b'_{Y2.13}$	−.8880	6.739	2.160	3.012
Thickness of pericarp	$b_{Y3.12}$	.05821	$b'_{Y3.12}$	.0366	.297	2.160	3.012

leaving the pericarp with its natural color, thus providing a clear differentiation between the two. Thickness measurements were taken at each end and on each side of the kernels with an ocular micrometer fitted into a microscope.

The results of the study are presented in tables 2 and 3. The thicknesses of the pericarps varied from 136 microns for Dixie 44 to 92.1 for Dixie 11. The regression coefficient of thickness of the pericarp was .05821, which was not significant (Table 3). Thus, it was concluded that the thickness of the pericarp was not related to the amount of rice weevil damage.

SUMMARY.—Studies were conducted in Alabama on the effects of components of husk cover and of kernel characteristics of corn on rice weevil damage at harvest. The work on the components of husk cover revealed that length of husk tip and number of leaves per husk were important constituents of husk cover in preventing damage by the rice weevil. The effect of each factor was independent of the other. The combined effects of both factors gave the least amount of weevil damage.

Hardness of corn varieties was measured by penetration of kernels with a 1/16-inch hollow steel punch and a Link spring checker. For each increase of one pound per square inch pressure required for penetration of the kernels, weevil damage decreased almost one per cent.

Although the mean thicknesses of kernel pericarps of the varieties studied varied from 92 to 136 microns, there was no correlation between the thickness of the pericarp and rice weevil damage.

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Organic Phosphate Dusts on the Plum Curculio[1]

J. H. COCHRAN[2]

The evaluation of various organic insecticides in dust compositions for the control of the plum curculio, *Conotrachelus nenuphar* (Hbst.), on peaches has been under way in South Carolina since 1949. Experiments conducted during 1949 and 1950 indicated that some of the organic phosphates were highly effective as dusts against this insect (Cochran, 1951). The present paper reports the results of experiments during 1951 with several of these organic phosphates.

Three groups of experiments were conducted in the laboratory on the adult plum curculio to determine: (1) the comparative effectiveness of several organic phosphates; (2) the effect of sulfur as a diluent on parathion and EPN dusts; (3) the effect of storage on parathion-sulfur dusts.

Dusts containing 1.5 per cent of the active compound were applied to excised peach twigs by a precision vacuum duster described by Farrar *et al.* (1949). The peach twigs were trimmed to give a uniform leaf area and the young growing tips were removed. Ten adult curculios were caged on each dusted twig and placed in the screened insectary. Mortality counts were made at 24 hour intervals for several days.

It was essential that the young growing tip of the twig be removed and that no undusted portion of the twig be exposed inside the screen cage. The dusts apparently were somewhat repellent to the curculios for they would cluster on the untreated areas.

The data in table 1 indicate a wide range in the effectiveness of the eight organic phosphates. Methyl parathion and EPN were more effective than parathion or malathon with methyl parathion being the most effective. The other four materials were much less effective.

The data in table 2 show that sulfur had little if any effect on parathion or EPN. However, sulfur has good fungicidal properties which makes it the preferred diluent for peach dusts.

Tests to determine the effect of storage on parathion-sulfur dusts indicate that these dusts can be stored in the original shipping bags in a dry place for at least one year without losing their effectiveness, but dusts that were stored for two years lost part of their insecticidal properties. The data from these tests are given in table 3. The high mortalities in some of the checks were probably due to the high temperatures during these experiments.

Field tests were conducted during 1951 to compare the effectiveness of parathion and EPN dusts and sprays. However, the curculio infestation in these plots was too low to show any significant differences between the various treatments, but the indications were that parathion and EPN when used in similar compositions were equally effective against the plum curculio. In these tests the dusts were applied according to the same schedule and on the same day as the sprays. The sprays appeared to be slightly more effective than the dusts. These data are somewhat contradictory to the results ob-

[1] Technical Contribution No. 199 from the South Carolina Agricultural Experiment Station, Clemson, S. C.

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Cotton States Program, 1952.

Table 1.—Comparative effectiveness of several organic phosphates on the adult plum curculio in the laboratory—1951.

Compound[1]	Dust, Mg. Used	Per Cent Control—Hours After Treatment					
		24	48	72	96	120	144
Parathion	50	43.3	65.0	66.7	70.0	73.3	76.7
	25	3.3	3.3	3.3	6.7	6.7	—
EPN[2]	50	76.7	100.0	100.0	100.0	100.0	100.0
	25	6.7	10.0	16.7	23.3	30.0	—
Malathon[3]	50	10.0	41.7	51.7	66.7	71.7	78.7
Methyl parathion[4]	50	95.4	100.0	100.0	100.0	100.0	100.0
	25	26.7	56.7	73.3	76.7	76.7	—
Systox[5]	50	15.0	21.7	23.3	26.7	33.3	45.0
4-methyl-umbellifrone o,o-diethyl thiophosphate[6]	50	1.4	8.3	6.7	11.7	31.7	41.7
Dithiophosphate tri ester[7]	50	13.3	20.0	20.0	25.0	33.3	48.3
Schradan[8]	50	10.0	16.7	10.0	15.0	35.0	38.3
Check	—	0.0	0.0	0.0	0.0	1.7	3.3

[1] All materials were tested as dusts containing 1.5 per cent of the active compound.
[2] DuPont Co. (EPN-300).
[3] American Cyanamid Co. (4049).
[4] Chemagro Corp. (Metadust).
[5] Chemagro Corp. (Systox).
[6] Chemagro Corp. (Potasan).
[7] Niagara Chemical Co. (ME3367).
[8] Monsanto Chemical Co.

Table 2.—Effect of sulphur on parathion and EPN dusts.

Material[1]	Dust, Mg. Used	Per Cent Control—Hours After Treatment				
		24	48	72	96	120
Parathion W/O Sulphur[2]	50	26.7	50.0	60.0	70.0	70.0
	25	3.3	3.3	3.3	6.7	6.7
Parathion With Sulphur	50	36.7	50.0	50.0	53.3	73.3
	25	0.0	0.0	0.0	0.0	6.7
EPN W/O Sulphur	50	63.3	90.0	100.0	100.0	100.0
	25	6.7	10.0	16.7	23.3	30.0
EPN With Sulphur	50	60.0	80.0	93.3	96.7	96.7
	25	23.3	26.7	36.7	36.7	36.7
Check—Untreated	—	0.0	0.0	6.7	6.7	10.0

[1] All materials were tested as dusts containing 1.5 per cent active material.
[2] Pyrophyllite was used as the diluent in the control samples.

Table 3.—Effect of storage on parathion-sulphur dust compositions.

Date Prepared[1]	Dust, Mg. Used	Per Cent Control			Chemical Analysis		
		Hours after treatment			% Parathion		% Decomposition
		24	48	72	Original	1-28-52	
1951	50	41.1	68.9	80.0	1.67	1.43	14.3
1950	50	41.1	71.1	75.5	1.59	1.38	13.2
1949	50	14.4	32.2	37.8	1.46	1.11	24.0
Check—Untreated—		2.2	3.3	6.7			

[1] These dusts were prepared by the Niagara Spray & Chemical Company during the spring of the year indicated and were stored at the Insectary at Clemson in unopened 3 or 4 ply heavy craft paper shipping bags.

Table 4.—Dates applications were applied on the orchard at Johnston—1951.

APPLICATION	DATE APPLIED
1st Petal-fall	March 22
2nd Shuck-off	April 5
3rd 1st Cover	April 19
4th 2nd Cover	May 31
5th 3rd Cover	June 23[1]
Peaches picked July 23—Elbertas	

[1] Due to insufficient space between the rows and to prevent excessive damage to the fruit and trees, dusts were applied to all of the plots by airplane. One replicate of all the treatments was dusted with parathion 1.5 per cent and the other replicate was dusted with EPN 1.5 per cent.

Table 5.—Comparative effectiveness of parathion and EPN dusts and sprays—Johnston, S. C.—1951.

PLOT	TREATMENT[1]	AVE. PER CENT WORMY PEACHES AT HARVEST
A.	EPN 1.0% with sulphur (dust)	3.2
B.	EPN 1.5% with sulphur (dust)	3.1
C.	EPN (spray) 1½ lbs. 25% WP plus 6 lbs. wettable sulphur/100 gallons	0.9
D.	Parathion (spray)[2]	0.8
E.	Parathion 1.5% with sulphur (dust)	2.7
F.	Parathion 1.5% with sulphur with 3% oil (dust)	0.9

[1] All dusts were applied at the rate of 40 lbs. per acre. The sprays on plots C & D were applied at the rate of 3.5 gallons per tree with a speed sprayer.

[2] A packeged parathion-sulphur-zinc spray. Thirteen pounds per 100 gallons. Parathion 1.7%; Sulphur 42.5%; Inert 55.8% including 10.75% zinc expressed as metallic.

tained during 1950 (Cochran 1951) when parathion dusts were equally as effective as parathion sprays, but in the 1950 experiments the dusts and sprays were not always applied on the same date and also the dusted plots received one additional application prior to harvest.

Also, included in the 1951 field tests was a parathion-sulfur dust (JE-600[3]) that contained 3 per cent oil (petroleum distillate). The control with this dust composition was equal to that obtained with the parathion spray. The dust containing oil appeared to build a heavier deposit on the leaves and fruit and it did not drift as much as the regular parathion-sulfur dust. There was no noticeable injury with this material; however, the oil dust did not flow through the duster as well as the other dusts. The dates of application and the data from the field tests are given in tables 4 and 5.

SUMMARY.—Eight organic phosphates were tested in the laboratory as dusts containing 1.5 per cent of the active compound on the adult plum curculio. EPN and methyl parathion were more effective than parathion or malathon. The other four materials were much less effective. Also, laboratory tests indicated that sulfur does not increase the effectiveness of parathion or EPN dusts; and parathion-sulfur dusts can be stored for one year in the original shipping bags without losing their effectiveness, but dusts stored for two years lost part of their insecticidal properties.

Field tests indicated that EPN and parathion were equally effective when applied in similar compositions. However, spray applications gave slightly better control than dusts. The addition of 3 per cent oil to the parathion-sulfur dust increased its effectiveness.

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[3] Prepared by Niagara Chemical Company.

Insecticides for Cotton Leafworm Control[1]

E. E. IVY and A. L. SCALES, *U.S.D.A., Agr. Res. Adm., Bureau of Entomology and Plant Quarantine*[2]

In times of insecticide shortage there is considerable interest in materials that may be substituted for currently recommended materials for control of

[1] Report of a study in which certain phases were conducted under the Research and Marketing Act of 1946.

[2] In cooperation with the Texas Agricultural Experiment Station.

Insecticides killing between 51 and 75 per cent of third-instar cotton leafworms.

INSECTICIDE	MAXIMUM DOSAGE TESTED
	Pounds per acre
Heptachlor	1
Tetraethyl dithiopyrophosphate	1
Tetraethyl pyrophosphate	1
Azobenzene	2
Chlordane	2
1,4-Diphenylsemicarbazide	8
Cryolite	10

Insecticides killing less than 51 per cent of third-instar cotton leafworms.

INSECTICIDE	MAXIMUM DOSAGE TESTED
	Pounds per acre
1-(*p*-Chlorophenyl)-2-nitro-1-phenyl-butane	0.5
Sabadilla (ground seed activated with 50% of lime)	1.6
Alpha isomer of benzene hexachloride	2.0
Beta isomer of benzene hexachloride	2.0
Delta isomer of benzene hexachloride	2.0
Epsilon isomer of benzene hexachloride	2.0
Chlorinated *p*-menthane	2.0
Octamethyl pyrophosphoramide	2.0
2,4-Dichlorophenyl ester of benzenesulfonic acid	2.5
Tung oil meal	8.0
Cape aloes	8.0
p-Aminoacetanilide	8.0

Table 2.—Results of bagging chestnut burs to determine the time of oviposition of the weevils.

Orchard	Date of Bagging	Number Bagged	Small Weevils	Large Weevils
Glenn Dale, Md.	July 12	65	0	0
1946	18	40	0	0
	26	67	0	0
	Aug. 1	71	0	0
	9	29	1	0
	14	88	3	2
	23	53	18	2
	29	53	23	11
1947				
	Aug. 15	54	5	1
	25	38	8	0
	Sept. 2	24	7	1
	9	42	18	4
	15	56	29	7
	22	90	47	11
	29	143	83	22
Fairfax, Va.	Aug. 26	35	9	1
	Sept. 10	58	25	4
	23	50	35	7
	Oct. 7	217	177	22
Elkton, Md.	Aug. 21	139	11	13
	Sept. 4	83	22	25
	18	116	21	35
	Oct. 1	108	31	44
1948				
Glenn Dale, Md.	Aug. 10	32	0	0
	20	20	0	1
	31	42	28	5
	Sept. 10	55	46	7
Fairfax, Va.	Aug. 7	54	4	1
	Sept. 8	55	39	6
	23	100	78	18
Elkton, Md.	Aug. 13	121	0	1
	Sept. 1	87	1	4
	Sept. 17	85	4	10
	Oct. 13	183	13	57
1950				
Glenn Dale, Md.	Aug. 7	87	0	0
	14	44	0	0
	21	50	0	0
	29	46	5	6
	Sept. 5	37	11	17
	Harvest	250	111	46

began emerging on August 8, 1949, whereas it was not until May 1, 1950, that the first small weevils appeared. Emergence of both species took place over a period of several weeks. No large weevils emerged during 1951. Of the 341 large weevils emerging, 82 per cent emerged in 1949 and the remainder in 1950.

Time of Oviposition.—To determine the time of oviposition of the weevils, cloth bags were tied over developing burs to prevent further egg laying in the nuts. At harvest the bags were removed and the nuts were held for observation. After all the larvae had left the nuts, they were examined for injury. The observations recorded in table 2 indicate that egg laying began about the second week in August and continued until the nuts were harvested.

Time Larvae Leave the Nuts.—About every other day chestnuts were gathered from beneath unsprayed trees and placed in wire baskets. At the time the nuts were picked up nearly all larvae were in the kernels. Only occasionally did a few of the large species drop to the ground while the nut was still attached to the bur. Therefore the records given in table 3 include all the larvae leaving the nuts. The first larvae left within a few days after the nut fell to the ground, and larvae continued to leave for many weeks.

The number of larvae feeding within a nut depends on the size of the nut. As many as 58 small weevil larvae have emerged from one large Japanese chestnut but the average number per nut was about 7. Often both species fed within the same nut.

Depth Larvae Burrow into Soil.—As soon as the larvae left the nuts, they worked their way downward into the soil by a writhing motion. Here they formed smooth-walled cells, which they occupied through the pupation period and until they reached the adult stage. To obtain information on the depth the larvae burrow into the soil, on September 10, 1949, many were distributed on the surface of Collington fine sandy loam soil. This type of soil ex-

Table 3.—Numbers of chestnut weevil larvae leaving the nuts at different times in 1945 and 1948.

Date 1945	Small Weevils	Large Weevils	Date 1948	Small Weevils	Large Weevils
Sept. 3	3	0	Sept. 11	0	1
4, 5, 6	7	4	12, 13	1	2
7	4	11	13	30	2
8	4	2	15	16	7
9, 10	12	0	16	106	8
11	36	4	17	118	8
12	88	7	18, 19	482	35
13	192	31	20	320	23
14	438	41	21	496	54
15, 16	698	61	22	692	34
17, 18	369	19	23	603	43
19	474	38	24	613	30
20	301	20	25, 26, 27	1425	35
21	158	13	28	499	19
22, 23, 24	394	23	29	259	8
25	34	3	30	181	10
26	78	6	Oct. 1	120	8
27	61	7	2, 3, 4	158	14
28	28	0	5	92	16
29, 30	80	7	6	8	3
Oct. 1	27	0	7	0	2
2	7	0	8	0	11
3	6	0	9, 10, 11	2	6
4	4	0	12	0	0
5	3	0	13	3	1
Total	3500	297	Total	6224	383

Table 4.—Distribution of chestnut weevil larvae at different depths in the soil.

Depth, in Inches	Number of Larvae		Percentage of Larvae (Cumulative)	
	Small	Large	Small	Large
0–1	66	14	2	5
1–2	243	68	10	31
2–3	461	99	25	70
3–4	602	31	45	82
4–5	616	29	65	93
5–6	274	12	74	98
6–7	331	1	85	98
7–8	362	0	97	98
8–9	77	0	99	98
9–10	17	0	99	98
10–11	3	3	99	99
11–12	1	1	100	100

tended to a depth of 15 inches. The subsoil was more sandy. In January 1951 the larvae were recovered at the depths shown in table 4. Most of them were at a depth of 3 to 5 inches. Those found in the upper inch appeared to be in a weakened condition. No lateral movement of the larvae was noted. It appeared that once a larva penetrated the surface it dug straight down. This type of soil permitted deep penetration. Where the soil is more firm, the larvae construct their cells nearer the surface.

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A New Method of Tagging Insects with P^{32}

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The usual method of tagging insects with radioactive phosphoric acid (containing P^{32}) is by incorporating the material in the larval rearing media or adult food. Hoffman *et al.* (1951) reported making flies radioactive by feeding them P^{32} in sugar solutions, and Yates *et al.* (1951) reported rearing mosquitoes in sugar solutions containing P^{32}. With some insects, such as plant feeders or predators, these methods of tagging may not be accomplished so easily; so tests were conducted to investigate other methods.

In the first tests flies and mosquitoes were sprayed with aqueous solutions of radioactive phosphoric acid in tightly closed chambers, but this method did not work very well even when wetting agents were added to the solution. Furthermore, spraying of radioisotopes may be an undue hazard for the operator. Since preliminary work had indicated that dipping insects in solutions containing P^{32} would make them sufficiently radioactive for use in ecological studies, further work was done with this method.

Males and females of two species of flies, *Musca domestica* (L.) and *Phormia regina* (Meig.), were immobilized with carbon dioxide and dipped individually for 10 seconds in a phosphoric acid solution containing 5 μc. of P^{32} per ml., with or without 0.1 per cent of the wetting agent Triton X-100.

Table 1.—Radioactivity (c.p.m.) of two species of flies dipped singly for 10 seconds in phosphoric acid solution containing 5 μc. of P^{32} per milliliter and 0.1 per cent of Triton X-100.

Species	After 1 Day		After 4 Days	
	No Wetting Agent	With Wetting Agent	No Wetting Agent	With Wetting Agent
Musca domestica	233	1750	181	920
Phormia regina	333	3717	286	2800

Table 2.—Radioactivity (c.p.m.) of three species of female flies dipped singly for 60 seconds in phosphoric acid solution containing 12.5 μc. of P^{32} per milliliter and 0.1 per cent of Triton X-100.

Days After Dipping	*Eucalliphora lilaea*	*Phormia regina*	*Musca domestica*
2	5900	5900	2250
3	3140	2160	1480
8	1630	2000	744
18	600	700	433

Upon removal they were placed on a screen in a cage to dry. If the insects were placed on paper, a large amount of the solution was removed by absorption. At intervals of a day or more after treatment, the flies were again immobilized with carbon dioxide and their radioactivity was measured individually at a constant distance of 0.25 inch from the end window of the Geiger-Müller tube. Table 1 shows the uptake of P^{32} by both species. Both males and females became radioactive. The addition of Triton X-100 increased the insects' radioactivity. Other wetting agents may perform equally well or better.

In another test females of the same species of flies and also of *Eucalliphora lilaea* (Wlk.) were dipped for 60 seconds in a solution containing 12.5 μc. of P^{32} per milliliter and 0.1 per cent of Triton X-100. Table 2 shows that the radioactivity of flies was increased by increasing the amount of radioisotope and the period of exposure. Radioactivity was measurable for 18 days. The radioisotope could be washed off but only after long, vigorous shaking in water. Dissection of these flies revealed very little radioactivity within the body, an indication that the material did not penetrate the cuticle or enter through the spiracles.

Other insects tested included wasps, several species of Coleoptera, grasshoppers, leafhoppers, and aphids, and all took up the P^{32}. About 80 per cent of the aphids died within 24 hours, but all other insects survived. The radioactivity per insect was dependent on its size and the amount of cuticle wetted.

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The Mite *Tydeus californicus* on Citrus and Avocado Leaves

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Tydeus californicus (Banks) is a small whitish mite commonly found on the underside of citrus and avocado leaves (Fig. 1). It tends to congregate along the midrib and veins; the junction of a vein with the midrib being apparently a preferred location. All stages, except the egg, may be found throughout the

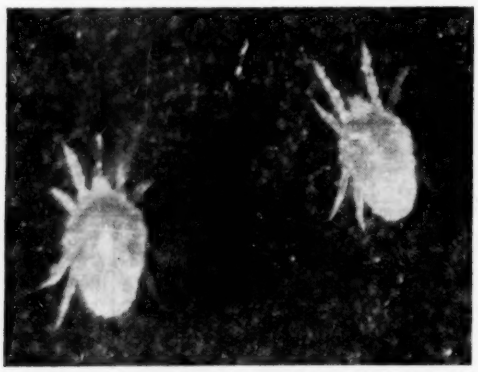

FIG. 1.—Adult female *Tydeus californicus* on under side of avocado leaf.

year. Eggs are rarely seen regardless of the population density of adult mites. This absence of eggs was quite puzzling until recent life-history studies revealed that the embryonic development is completed within the body of the female mite. The development of the embryo within the mother progresses so far, in fact, that the larva at times starts emerging from the egg while the egg is being laid; in any event the egg hatches within a few minutes after oviposition. The discovery of this type of larval development in *T. californicus* was quite unexpected as it has not previously been reported in this family of mites.

Until the present, *Tydeus californicus* has been considered a predator or fungus feeder of no economic importance. Baker & Wharton (1952) state that mites of the family of which *T. californicus* is a member are world-wide in distribution, and appear to be predaceous on small insects and mites and their eggs. They state also, however, that there is an indication that certain species may be plant feeders but that more observation is necessary. It was rather surprising, therefore, to discover that *T. californicus* feeds and reproduces on avocado leaves free of fungus, insects or other mites. Careful observation with the aid of a microscope showed that immediately after hatching the young mites also settle down to feed on the leaf surface.

Tydeus californicus is easily confused with the six-spotted mite when observed in the field. This is true because both species are light in color, inhabit the same general areas of the leaves, and both tend to occur in larger numbers in the costal areas. They may be readily separated, however, by the presence of feeding symptoms on the leaves. The six-spotted mite, even when present in relatively small numbers, will cause a discoloration along the midrib and veins where feeding is concentrated. *T. californicus*, however, produces no obvious feeding injury even when present in large numbers.

It must not be assumed that *Tydeus californicus* is harmless to the tree simply because it does not produc obvious feeding injury. On the contrary, since this mite feeds on the leaves and often occurs in numbers well over 100 per leaf it must be suspected as a possible pest until proven otherwise.

Because of the above findings, concentrated studies on the life-history and habits of *Tydeus californicus* and its natural enemies are now in progress. In addition, cooperative field studies with Dr. Walter Ebeling of the Department of Entomology, University of California at Los Angeles, have been initiated to evaluate the effect of acaracides and insecticides on *T. californicus* and its natural enemies in avocado groves.

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The Effect of Lindane Vapor on Canaries and Pigeons

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A number of domestic animals have been exposed to continuous applications of lindane vapor (Sweetman and Spear 1952) during experimental testing for insect control for varying periods of time from a few days to several months. The animals included cattle, horses, sheep, pigs, rats, chickens, pigeons, canaries and tropical fish. No apparent harmful effects were detected among the cattle, horses, sheep and hogs (Sweetman *et al.* 1951; Moore *et al.* 1951). The tests with rats and chickens are still in progress. The only animals exhibiting toxicity to recommended dosages of lindane vapor have been canaries and tropical fish. The effect on tropical fish is being published in a separate paper (Schulze *et al.* 1952). The results with pigeons and canaries are reported in this paper.

MATERIALS AND METHODS.—Lindane was dispersed by continuous vaporization from an electrically heated instrument[2] that is thermostatically controlled. Sweetman & Spear (1952) have tested this new device which provides a dependable, durable, clean, automatic and relatively safe method of applying insecticides. The common commercial rate of vaporization is approximately 1 gram of lindane per 20,000 cubic feet per 24 hours (Haller & Simmons 1951). Such amounts appear to be well within safe limits for man while giving effective control of a number of insect pests.

Five canaries were used in a series of tests. Four were exposed to lindane vapor and one was kept as a control. The tests were conducted in an unoccupied dormitory with the windows closed. The electrical room (870 cu. ft.) in the basement and areas (14,000 cu. ft.) on the second and third floors were utilized. The birds were retained in small wire cages 5 by 9 by 6″ high. During the period of exposure the average temperature remained between 70 and 80 degrees F. and the relative humidity between 40 and 50 per cent. Tri-weekly observations were made of the appearance and responses of the birds at which time

[1] Contribution from the Department of Entomology, Univ of Mass., Amherst.
[2] Manufactured by American Aerovap, Inc., New York City.

food and water were replenished and the cages cleaned.

The pigeons were treated under normal loft conditions. Two lofts were treated, containing a total of 75 birds, which ranged in age from newly hatched to 10 years. Six breeds were represented. The lofts were exceedingly open in their construction so that a high degree of ventilation existed. High vaporization rates were used to allow for this (Table 1). No analytical work was undertaken on pigeons, but the health of the birds was carefully observed during and for an extended period following the exposure.

Table 1.—The effect of lindane vapor on canaries and pigeons.

Test Number	Exposure: Days	Exposure: Gm./20,000 cu. ft./day	Health Before	Health During Exposure	Health Following
		Canaries			
1	34	1.60	Excellent	Good	Fair
2	34	2.47	Excellent	Poor	Poor
3	a-34[1]	1.60	Excellent	Excellent	Excellent
	b-43[2]	12.41	Excellent	Fair	Poor
4	4	14.02	Excellent	Poor	Died
5	Control		Excellent	Excellent	Excellent
		Pigeons			
6 Loft 1[3]	14	3.10	Excellent	Excellent	Excellent
7 Loft 2[4]	14	20.55	Excellent	Excellent	Excellent

[1] Re-exposed after 29-day interval.
[2] Intermittent exposure with the canary being exposed for 15 of the 43 days.
[3] Contained 40 birds of varying ages.
[4] Contained 35 birds of varying ages.

Both biological and chemical assays were used in testing for the presence of lindane in the canaries. Muscle tissue was used for analysis since an inadequate amount of fatty tissue could be collected. Chemical extractions and analyses were carried out in the Department of Food Technology[3] by the method of Davidow and Woodard (1949). For biological assay house flies were placed in 600 ml. Erlenmeyer flasks containing a tissue extract. The flies were fed and mortality determined at the end of 24 hours.

DISCUSSION AND RESULTS.—Canaries are apparently sensitive to lindane vapor at dosages slightly above commercial concentrations of one gram per 20,000 cubic feet per day (Table 1). When the canaries were exposed to relatively low concentrations for 34 days, No. 2 became very sick, No. 1 slightly ill, while No. 3 exhibited apparent excellent health. A biological analysis of tissue extract from canary No. 1 yielded 20 per cent fly kill in 24 hours. Bird No. 2 recovered in three weeks after removal to air free of lindane vapor.

No. 3 canary was re-exposed to a heavy dosage of lindane vapor after an elapse of 29 days in a lindane free atmosphere. Each time the bird became sick it was removed and allowed to regain its health. This process of intermittent exposure continued for 43 days with the canary being exposed for 15 days during that time. Sixty-nine days after the exposure period the bird was sacrificed for chemical analysis. Chemical analysis revealed no lindane. No hypersensitivity was apparent from the repeated exposure. The lindane was apparently eliminated from the body of the canary during the rest period following exposure. This complete elimination of lindane is in line with findings of others (Lehman 1950) working with cattle.

No. 4 canary was exposed in a heavy dosage of lindane vapor and died after four days. A muscle extract gave a 100 per cent fly kill in 24 hours. The symptoms exhibited by the sick birds were loss of appetite, droopiness, lack of coordination and finally death.

The pigeons were exposed to heavy dosages of lindane vapor, ample to eradicate lice on the birds in 24 hours (Moore 1952). The high ventilation of the lofts may have dissipated the vapor rapidly so that a heavy concentration did not accumulate (Table 1). The birds continued laying, incubation, and brooding of squabs in both lofts during the treatments. No unusual reactions or apparent harm from the exposures were noted. None of the birds were sacrificed.

CONCLUSIONS.—Canaries were sensitive to concentrations of lindane somewhat in excess of that recommended commercially. Upon exposure to dosages 12–14 times greater than commercially recommended rapid development of toxic symptoms occurred. No hypersensitivity developed with a canary subjected to repeated exposures. Pigeons from newly hatched to ten years of age apparently suffered no ill effects from high dosages of lindane vapor.

The results suggest that canaries should not be exposed to lindane vapor, even at commercially recommended rates of approximately 1 gram per 20,000 cubic feet per 24 hours. Pigeons can be safely exposed to lindane vapor in amounts adequate to eradicate lice (Moore 1952).

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Toxicity of Lindane Vapor to Tropical Fish

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The recent development and widespread use of continuous space treatment with insecticides, applied by continuous vaporization (Sweetman & Spear 1952), for control, eradication, and prevention of infestation of various structural pests has posed the question of possible toxicity hazards to man and his pets that are maintained in such atmospheres. This report deals with the results of tests wherein tropical fish were maintained in aquaria exposed to and aerated with atmosphere containing the vapor of lindane. Information regarding the effect of continuous space treatment at recommended rates[1] on birds, fowls, and man and other mammals is reported elsewhere (Spear & Decareau 1952, Moore 1952, Tatro 1952).

These tests were conducted in the home of the senior author, who is experienced in the handling and maintenance of tropical fish in home aquaria. The experiments were conducted on the ground floor of a two-story dwelling with basement. The upstairs and basement were closed off from the ground level except as doors were opened during normal passage of members of the family. The family consisted of 2 people. The family dog spent a major portion of its time in the house, much of the time exposed to the lindane vapor. The treated area comprised about 6000 cubic feet. The exposure to treated atmosphere was conducted during the months of September and October. Ventilation was at a minimum during working hours since both members of the family were out of the house, although they were home for lunch. At other times normal ventilation was maintained.

The vapor was applied with an automatically controlled electric vaporizer for a period of 55 days during which time 53.28 grams of lindane were vaporized. This was at the rate of 0.9687 grams per day or approximately 2.4 times the recommended commercial rate for the space involved. The vaporizer was operated at a distance of 4 to 10 feet from the aquaria. Slade (1945) states that lindane is soluble in water to 10 ppm. at 20° C. and that 1 ppm. is lethal to goldfish.

The tropical fish were maintained in two 10-gallon tanks and a 2-gallon tank mounted on stands 27 inches from the floor in a 12 by 14 foot room opening into other first floor rooms on two sides. The large tanks were equipped with filters which also aerated the water; 1 tank had an air-stone aerator. Room air was pumped into the tanks with an electrical compressor motor. All tanks were equipped with thermostatically controlled heaters which maintained a water temperature of 73° to 75° F. The large aquaria were covered with glass except for small openings for entrance of the thermostat, heater cord and filter tubes. The environmental conditions were similar to those of dealers (Innes 1949, Fraser-Bruner). Lindane contamination came from water surface absorption or from air pumped into the tanks. Air was not forced into the two-gallon tank and it was covered except for a space of about an inch at one end of the aquarium.

The aquaria contained 11 species of tropical fish belonging to 3 orders and 6 families, numerous snails and plants (Table 1). The small tank contained two male *Betta splendens* separated by a glass plate which allowed free circulation of water throughout the tank. This tank lacked forced aeration but was well-supplied with plants; also this species has an

[1] Interdepartmental Committee on Pest Control 1951.

Table 1.—The species of fish tested and the mortality resulting from exposure to atmosphere containing lindane vapor.

COMMON NAME	ORDER, FAMILY AND SPECIES	NUMBER PRESENT	NUMBER DIED
Guppy	Microcyprini	85±	76±
	Poeciliidae		
	Lebistes reticulatus (Peters)		
Black Mollie	*Molliensia spenops* (Cuvier & Valenciennes)	4	4
Blue Moon[1]	*Platypoecilus maculatus* (Guenther)	—	—
Kissing Gourami	Labyrinthici	2	1
	Anabantidae		
	Helostoma temmincki (Cuvier & Valenciennes)		
Paradise Fish	*Macropodus opercularis* (L.)	4	4
Siamese Fighter	*Betta splendens* (Regan)	2	2
		2[2]	1
Thick-lipped Gourami	*Colisa labiosa* (Day)	1	1
Zebra	Ostariophysi	3	3
	Cyprinidae		
	Brachydanio rerio (Hamilton-Buchanan)		
Pink Danio[2]	*Brachydanio albolineatus* (Blyth)	—	—
Talking catfish	Doradidae	1	1
	Acanthodoras spinosissimus (Eigenmann & Eigenmann)		
Leopard catfish	Callichthyidae	1	1
	Corydoras julii Steindachner		
Catfish	*Corydoras Paleatus* (Jenyns)	1	1
Plecostomus	Loricariidae	2	0
	Plecostomus (L.)		

[1] Not exposed to lindane.
[2] Placed in aquarium on 56th day.

Table 2.—The toxicity to house flies of whole tissue extracts from fish retained in tanks contaminated with lindane vapor and from untreated fish. Ten 3-day old flies were enclosed in each flask.

No. of Hours	Number of Flies Dead from Extracts of Fish Exposed to Lindane					Number of Flies Dead from Extracts of Fish not Exposed to Lindane and Control Flasks			
	Guppies								
	1	2	Zebra	Zebra and Guppies	Paradise	Guppies	Blue Moon	Pink Danio	Flask
2.0	3	10	10	8	4	0	0	0	0
3.5	8	10	10	10	8	0	1	1	0
5.5	10	10	10	10	9	0	4	1	0
21.0	10	10	10	10	10	0	4	0	0

auxiliary lung apparatus which allows it to utilize oxygen from the air as well as from the water through the gills. One ten-gallon tank contained a scavenger plecostomus, a pair of black mollies, a kissing gourami, numerous guppies, 3 zebras, 4 paradise fish, 3 catfish; all of various ages, plus snails and plants. The other ten-gallon tank had 1 plecostomus, a pair of black mollies, a kissing gourami, a thick-lipped gourami, guppies, snails and plants.

During and after exposure to the lindane vapor the tanks were maintained as during the preceding year and a half. The fish were fed once daily; aged water (water allowed to stand 72 hours in a glass container) was added from time to time to replace that which evaporated, and tanks were cleaned of excessive fecal waste and dead or soft plants at intervals of 2 to 4 weeks. The aquaria were observed thrice daily for evidence of contamination or signs of disease.

Responses, illness and mortality of the fish were noted and recorded to determine possible toxicity of the lindane. Fish that died during the 55 days that lindane was vaporized and those that died from later exposure in contaminated water were analyzed chemically for lindane content and extracts tested biologically for toxicity to house flies, *Musca domestica* L. Dead fish were removed as soon as observed and quick-frozen until analyses could be made. The analytical methods were, in the earlier analyses (Table 2) that of Davidow & Woodard (1949) and the later analyses (Table 4) that of Schecter & Hornstein (1950). The extracts for bio-assay tests were prepared by members[2] of the Food Technology Department of the University of Massachusetts and placed in 1000 cc. Erlenmeyer flasks in solution with carbon tetrachloride. The solvent was evaporated leaving the lindane in the flasks. Ten house flies, rendered inactive with carbon dioxide, were placed in each flask and observed for toxic effects.

The first bio-assay was prepared from 2 lots of fish that died including a number of guppies and a single gourami. Extracts of these fish when tested still contained traces of carbon tetrachloride, which produced some mortality among the flies and gave erratic results. However, the mortality was much less in the control flasks, clearly indicating a substance, presumably lindane, in the extracts that was toxic to the flies. The second series of bio-assay tests included 5 species, tested separately. The series included a kissing gourami, catfish, Siamese fiighter, zebra, and a number of guppies (Table 1). The guppies were combined for a single extraction. Caution was used to eliminate all carbon tetrachloride as a contaminant. Here again the mortality among the flies exposed to fish extracts was near 90 per cent, while the controls showed 10 per cent or less.

The results from a third bio-assay series included fish that had succumbed in lindane contaminated water after vaporization was discontinued and unexposed fish that were sacrificed for the bio-assay. The unexposed fish, including 2 pink danios, 2 blue moons and 10 guppies (Table 1) were obtained from a dealer. It is quite obvious that the exposed fish contained a toxic substance, presumably lindane (Table 2). It was deemed desirable to use control fish in these tests since some earlier extracts from unexposed fish had been quite repellent to the flies.

The first recognized evidence of toxicity was detected after 22 days when a single female guppy died (Table 3). A number of deaths followed at frequent intervals without appreciable change until the vaporizing unit was removed after 55 days. It was possible for a fish to succumb and be eaten by snails and scavenger fish between observations. Following discontinuance of vaporization of lindane there was an appreciable drop in the number of deaths during November, although the majority showed signs of illness.

Illness, presumably attributable to lindane, was manifested by droopy fins, lethargic movements, hovering near the surface of the water, and exhibiting hyper-nervousness and sensitivity. This sensitivity was so extreme that any vibration in the room caused the fish to swim violently around the tanks and often jump out of the water and against the cover of the aquaria. Some fish showed hemorrhaged gills as an early symptom, with this condition gradually extending over the entire body. The larger fish frequently went into violent "fits"; swimming wildly with no apparent direction, even smashing into slides of the tanks, often jumping out of the water and hitting the cover. The swim bladder of the Anabantidae, which utilize oxygen from the air as well as the water, seemed to be affected so that these fish were unable to gain depth and, of necessity, stayed at the surface. Occasionally, the bladder was so distended that the fish protruded from the water.

On the 90th day, early December, the nervousness appeared to reach a stage where large numbers of fish, mainly male guppies, jumped out of the tanks. Since there was only a small area over the aquaria that was not covered, the larger fish may have been restricted from escaping. Jumping from the tanks accounted for approximately one-half the deaths that occurred during the next 36 days.

[2] R. V. Decareau & Dr. M. C. Tatro.

Table 3.—The mortality of aquarium fish during the period of observation from May 1, 1950 to October 1951.

MONTH	NO. OF DEATHS
Preceding Exposure	
May	1
June	0
July	2
August	2
Vaporization Period—55 Days	
September	2
October	12
Following Exposure	
November	3
December	24
January	7
February	7
March	6
April	9
May	7
June	20
July	22*
August	1
September	7†
October	1

* Majority of deaths occurred while moving the fish a distance of 120 miles.
† Produced by disease.

Water from lindane exposed tanks was evaporated to form a residue. Two 100 cc. samples were used, one containing water with aquatic plants, the other water only. The residue was tested biologically to determine if toxic to flies (Table 4). Both residue samples killed flies although the one with aquatic plants did so less rapidly. Presumably the lindane absorbed in the plants was deposited externally as the tissues dried.

The experiments were continued to ascertain how long aquaria contaminated with lindane might remain lethal. On the day vaporization was discontinued 2 young *Betta splendens* were purchased and placed in the small tank to replace those which had died, to ascertain if the water retained sufficient lindane to remain toxic. Eighty-three days later these fish were still alive, but had not grown appreciably as normally they should have. One of these fish, after remaining in the contaminated water for 138 days was transferred to a clean tank and water along with other fish (Table 5, Lot 8). At death its tissues were free from lindane.

Table 4.—The toxicity to houseflies of residue from water and plants from tanks contaminated with lindane vapor. Fifteen 7-day old flies were enclosed in each dish.

NO. OF HOURS	MORTALITY—NO. OF FLIES		
	Residue from Water and Plants	Residue from Water Only	CONTROL
2.25	0	0	0
5.00	0	5	0
7.25	0	9	0
19.50	11	10	1
22.00	11	11	2
24.00	13	13	3

Table 5.—The relative amounts of lindane recovered from fish exposed in water contaminated as determined by chemical analyses.

LOT NO.	DAYS FISH WERE EXPOSED TO			WEIGHT OF SAMPLE, Grams	LINDANE RECOVERED	
	Vapor	Contaminated Water	Contaminated Fish Only		mg.	p.p.m.
1	0	0	0	0.578	0.009	3[1]
2	55	84–184	—	2.158	0.073	31
3	55	127–139	5–19	1.609	0.031	16
4	55	127–139	19–52	2.578	0.047	15
5	55	197–246	—	4.113	0.012	0
6	55	197–246	—	2.251	0.006	0
7	0	0	68	2.032	0.008	1
8	0	138	170	1.931	0.007	1

1. Five pairs of guppies purchased from supplier and analyzed without exposure to lindane for check purposes. Considered negative since the sensitivity of the method was considered to be 5 p.p.m.
2. Guppies, zebra and Siamese fighter.
3. Guppies.
4. Guppies and catfish.
5, 6. Guppies *et al.*
7. Dwarf gourami.
8. Siamese fighter.

The fish were continued as before in the 2 ten-gallon tanks. They were observed closely for symptoms of lindane poisoning as opposed to other tropical fish diseases. No new fish were added to these aquaria. Mortality among these fish continued for many months (Table 3). The dead fish were quick-frozen and stored until analyses could be completed. Three separate analyses were made (Table 5, Lots 2, 5 and 6). Apparently the tanks and water had become decontaminated before 200 days had passed.

A new 20-gallon aquarium, never exposed to lindane, was equipped similarly to tanks already present. Twenty-four fish (20 guppies, ½ females, 1 leopard catfish, 1 kissing gourami, 1 plecostomus and 1 Siamese fighter) were transferred to this tank from aquaria previously exposed to vaporized lindane to determine if recovery from lindane poisoning occurred. After a period of observation, typical symptoms of lindane poisoning were still present although of less severe manifestation. Deaths occurred during the next 52 days (Table 5, Lots 3 and 4), It appeared that lindane was being rapidly eliminated since these fish contained about half as much lindane as Lot No. 2.

Symptoms of lindane poisoning were evident among the fish that remained in the contaminated tanks and water as long as 252 days after the experiment began or 197 days after the vaporizing unit was removed. Fatalities of fish up to, and after, 301 days from the first exposure to lindane vapor occurred. Analyses of these fish showed no lindane (Table 5, Lots 5 and 6) but it was felt that long exposure to the insecticide had caused a general debility with a resulting shortening of life span and inability to withstand minor changes in the environment (Table 3).

Several unexposed fish were placed in the 20-gallon tank, which was lindane free, along with the other fish from the contaminated tank and water. These new fish did not develop any of the symptoms typical of lindane poisoning. One, a dwarf gourami that died after 68 days was analyzed for lindane (Table 6, Lot 7). Its death was not a result of lindane poisoning.

SUMMARY.—Tropical fish were exposed to lindane vapor and to aquaria water contaminated with lindane. Thirteen species of fish were tested during the experiment. The fish were maintained under favorable environmental conditions except for lindane vapor in a private home by an experienced handler. The vaporizer was operating for 2 months, but observations of the fish were continued over a period of 18 months. The symptoms of lindane illness are described. Bio-assays with fish extracts and chemical analyses were made to determine if mortality among the fish was a result of lindane poisoning.

CONCLUSIONS.—Lindane is absorbed in the water of tropical fish aquaria when exposed to lindane vapor. This occurred when air containing lindane was bubbled through the water and in aquaria where only a small portion of the surface was open to the exposed air. Tropical fish are very sensitive to lindane as symptoms developed in a few weeks following exposure to the vapor. Fish retained in water contaminated from exposure to lindane vapor when only replenishment of evaporated water occurred, showed lindane in the tissues for many weeks. Tropical fish are slow in recovery from lindane poisoning.

There was no apparent correlation between size and susceptibility for not only small fish such as guppies succumbed, but also ones several hundred times the size of guppies.

RECOMMENDATIONS.—It is recommended that vaporized lindane not be used in homes or buildings housing tropical fish. If an exposure to lindane should occur, the following remedial plan should be carried out. Fish should be removed from the aquaria. Gravel, plants, and water should be discarded, and new aged water should be placed in the tanks along with fresh gravel and aquatic plants. The fish then may be replaced in the aquaria. The water should be changed every week or two until all symptoms of lindane poisoning disappear.

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Rooted Lemon Fruits for Citrus Pest Studies

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A number of host plants have been used for laboratory culture of citrus pests and their natural enemies in toxicological and biological control research. Principal among these are fruits of lemon, grapefruit and orange, seedlings or rooted cuttings of various citrus varieties, banana squash, citron melons, potato sprouts and potato tubers (Flanders, 1949). Each of these may have specific advantages, most have general disadvantages.

Citrus fruits, especially lemons and grapefruit have been used particularly for the culture of the California red scale (Yust and Munger, 1943), its natural enemies (Henderson, *et al.* 1943; Flanders, 1951) other diaspine scales and the citrus red mite. They are also suitable hosts for citrus mealybugs and undoubtedly other citrus pests which have not been tested. Citrus fruits produce larger diaspine scale individuals more rapidly and with more resulting progeny and the per cent settling of young is higher and subsequent mortality lower than on other parts of the citrus plant (Bliss *et al.*, 1931; Mathis 1947; Bodenheimer 1951, p. 236). Lemon fruits have the advantage over other citrus fruits of being available from one district or another, throughout the year. Banana squash and citron melons also produce large diaspine scales rapidly but the large size of

FIG. 1.—California red scale cultured on a lemon fruit with short stem and roots attached. Uninfested lower portion of fruit was covered by sand. Photographed 4 months after removal from tree.

these host plants and the fact that they are not citrus, present certain biological disadvantages.

The principal disadvantage to the use of citrus fruits for pest culture purposes has been the relatively short life of the fruit because of desiccation. Various attempts have been made to overcome this. Henderson *et al.* (1943) described a method of keeping lemon fruit turgid for as long as 60 days by a

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combination of waxing the distal end and keeping the stem end in wet sand. It occurred to the authors that rooted lemon fruit would be a much simpler method of maintaining turgidity and prolonging the life of lemon fruit for laboratory study purposes particularly if low humidity studies were to be involved. Subsequent tests proved the idea to be practical.

Lemons, especially large green fruits, may be cut from the tree with an inch or so of stem attached and rooted easily in sand under suitable glasshouse conditions (Fig. 1). A much better proportion of rooting occurs if the cut stems first are dipped in 0.2 per cent naphthaleneacetic acid powder.

Such rooted fruits may remain in a turgid healthy condition for as long as six months under glasshouse conditions. Changes in coloration from green to yellow occur very slowly. The California red scale, ivy scale, and citrus red mite have been successfully cultured on rooted lemons. Excessively heavy initial infestations of the California red scale may lead to premature fruit collapse probably because of the action of digestion enzymes secreted by the scales into the fruit. Low initial infestations will permit the successive development of two and perhaps three scale generations, however. In order to reduce rots, fruit should be dipped in a warm 3 per cent solution of sodium tetraborate (borax) as described by Yust & Munger (1943).

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Dermal Treatment of Rats with Toxicants

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The principal difficulty of applying a toxicant to the skin of an animal and leaving it there any length of time: testing for toxicity by skin penetration only, is the animal's habit of licking itself, thus taking the material internally. To keep this from occurring the following apparatus and technique have been devised and successfully used with such highly toxic materials as parathion and other organic phosphates.

CAGE: This is a cone of 0.5 inch mesh hardware cloth, 13 inches long and 2.25 inches in diameter at its base tapering to a 0.75 inch apex. A 1-inch square metal tag is attached for numbering and a heavy wire hairpin shaped clip is used as a backstop.

PREPARATION AND TREATMENT OF ANIMAL.—Clip with the scissors and shave with an electric razor, not too close, an area on the back extending from the base of the tail to the shoulder blades and down the sides to a line just above the hip bone. Weigh the animal in grams. Hold the cage with the small end up toward the light and allow the rat to crawl into it until there is a snug fit. Immediately place a ball of paper toweling behind the rat and below its tail, securing the towel with the clip through the meshes of the wire and forked over the tail. Number the cage on the metal tag and place on a wire mesh stand; the rat's head away from the light. Apply the toxicant with a 1.0 ml. or smaller pipette to the shaved area at the calculated dose. If possible hold the dose to 0.3 ml. or less so there will be no excess to get into the surrounding hair. Allow it to act for at least 6 hours, the rat neither being fed nor watered during this time. Remove the toxicant by flushing the treated area, thorax and abdomen with 500 mls. of acetone or isopropyl alcohol while the animal is in the cage. Immediately follow with a warm water rinse. Release the wire clip, remove the wad of paper and turn the cage with the animal pointed end down into a shaded corner, giving a slight pull to the tail. This normally causes the rat to back out quickly. Wash with soap and warm water using a soft bristle brush and rinse with warm running water. Dry thoroughly with cloth towels. Number the animal on the shaved area with a dampened blue indelible pencil and place in a large cage having food and water also; crumpled paper towels for warmth. Observe symptoms and general health for 10 days.

The Chicken Mite Attacking Children

WAYNE L. BERNDT

On July 12, 1952, John A. Lofgren, South Dakota Extension Entomologist, received several mites for identification from a family residing near Bison South Dakota. The children of the family, while playing in a particular room of the home, had been bitten by something which the parents could not immediately locate. After careful search, the parents found several mites on a window sill of a play room; these mites were sent in as possible suspects of the attack on the children.

The mites were referred to the writer by John Lofgren for identification. The mites were identified as *Dermanyssus gallinae* De Geer, the common chicken mite.

Correspondence yielded the information that numerous sparrow nests were lodged under the eaves of the house. These nests were heavily infested with *Dermanyssus gallinae*, and population pressure, hunger, and climatic conditions evidently were causing the mites to migrate. Some of the mites were making their way into the play room and attacking the children. The attacks of the mites, according to the mother, were painful, but the children did not develop any dermatitis as a result of the bites.

The parents were instructed to remove and burn all the bird nests from under the eaves of their home. This was done with the consequence that no more mites invaded the home and the children were no longer bitten.

An Improved Cage for Flies[1]

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An often serious problem in rearing house flies and blow flies in the laboratory is the uncanny ability of the adults to escape from cages during the servicing of the captives. Various devices have been tried in an effort to minimize this, such as small doors, sleeves, etc. None of these, however, prevent the escape of some flies. In fact, it is probably impossible to prevent escapes as long as it is necessary to open cages containing flies for servicing with water, food, and oviposition media. A possible solution to the problem has been suggested by Harrison (1949) who supplies these items in modified test-tubes which are inserted through very small openings in the cages.

We have solved the problem in what we think is a simpler fashion. In our technique, we no longer open the cages after the fly pupae have been put in them. The cages are made to close completely, one side being a tight fitting lid which serves as the bottom of the cage and which is held in place, if necessary, by a string tied tightly around the cage.

Water, and milk when needed, are supplied in wide-mouth bottles covered with three or four thicknesses of cheese-cloth which are inverted on the top of the cage. Once the cheese-cloth is wet, the fluids do not leak out. The flies reach through the screening of the cage and imbibe the liquids from the moist cheese-cloth. It should be noted that this method of furnishing fluids is not original with us. We observed its being used with milk in the laboratory of Dr. W. N. Bruce at the Illinois Natural History Survey: the present report, we believe, is the first in which this method has been recommended for use with all fluids furnished to flies. Sugar is given to the flies by being scattered about in cube form over the top of the cage.

The presentation of oviposition materials gave us some difficulty at first. Reasoning from past experience, we placed these in dishes beneath the cages, outside the screening and touching it. This necessitated elevating the cage in a level position to the height of the dish containing the oviposition material, an unsatisfactory procedure. Fortunately, however, the flies were not affected by previously tried techniques. Therefore, when we tried inverting Petri dishes of the oviposition media on top of the cage over the screening the flies oviposited just as well—if not better. The flies were introduced as pupae, the cages are closed and sealed, if necessary, and from then on escape is impossible, because the cages need not be reopened.

If it is necessary to withdraw flies from these cages for experiments, this is easily done by allowing them to crawl into a bottle through a small hole in the top of the cage using a light to attract them. When not in use, this hole may be closed with a small piece of adhesive tape or plugged with a small cork or bit of cotton.

It is interesting to note that the oviposition medium need not even touch the screening to secure eggs from the flies. We have determined the maximum distances at which house flies will oviposit, and a report of these results will be made separately. This species, for instance, will oviposit vertically upward just as well when the medium is within 5 mm. of the screening as when in contact.

Three species of flies, *Musca domestica*, *Phormia regina*, and *Sarcophaga bullata*, have been successfully maintained in these cages. They have been reared by the method of Frings (1947, 1948) using fermenting dog-biscuit as the larval medium for house flies and moistened non-fermenting dog-biscuit for the others. With the house flies we have also used moistened fermenting commercial mouse-diet as the larval medium. This has proved quite successful; in fact it seems to be superior to dog-biscuit. It has the same obvious advantages over the older materials as does dog-biscuit—compounding of the larval medium is unnecessary and odors are not so great a problem. Blow flies oviposit and flesh flies larviposit through the cages onto small pieces of fresh meat. These are transferred to rearing jars containing dog-biscuit.

Since our laboratory is in a class-room and office building, it is necessary to keep escaped flies and odors at a minimum. The methods described here have proved quite successful, and they are offered in the hope that others with similar problems may benefit.

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Control of the Pecan Weevil in Texas

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In 1950 and 1951 several of the new insecticides were tested for the control of the pecan weevil in Texas. DDT, toxaphene, dieldrin, heptachlor, and EPN were tested as sprays, and ethylene dibromide. BHC, and DDT as soil treatments. The results are incomplete, because the work in Texas was discontinued early in the fall of 1951. DDT (Moznette 1947) and toxaphene, parathion, and EPN (Osburn 1950 and 1952) had already been reported as giving good control in Georgia.

SPRAYING EXPERIMENTS.—The spray applications were timed by observations on weevil emergence. Weevils did not emerge in numbers until after rains occurred. When weevil-injured nuts were found, 5 to 10 trees were jarred to determine whether enough weevils were present to make spraying worth while. Spraying was done from the ground with a power machine at a pressure of 500 to 600 pounds per square inch. A single-head gun was used. The experiments were conducted in randomized blocks. with 6 to 10 one-tree replicates.

In 1950 experiments were conducted in two orchards. In one orchard, at Brownwood, the variety used was Burkett. Two well-timed applications were made, on September 6 and 15. Since the black pecan aphid, *Melanocallis caryaefoliae* (Davis), was abundant, 7 fluid ounces of nicotine sulfate (40 per cent nicotine) and 2 quarts of summer oil per 100 gallons were added to the sprays applied on September 6. The results on examination of 250 nuts harvested from each tree are given in table 1.

Table 1.—Results of spraying experiments against the pecan weevil, Brownwood, Texas, 1950.

Materials	Quantity per 100 Gallons	Harvested Nuts Infested
		Per Cent
DDT (50% wettable powder)	6 lb.	6
Toxaphene (50% emulsifiable concentrate)	1 qt.	39
Unsprayed	—	68

Table 2.—Results of spraying experiments against the pecan weevil, Gustine, Texas, 1950.

Materials	Quantity per 100 Gallons	Infested Nuts	
		On Tree Sept. 7–11	At Harvest
	Pounds	*Per Cent*	*Per Cent*
Dieldrin (25% wettable powder)	2	52	—
DDT (50% wettable powder)	6	27	75
EPN (27% wettable powder)	2	74	99
Unsprayed	—	89	99

Table 3.—Results of spraying experiments against the pecan weevil, San Angelo, Texas, 1951.

Materials	Quantity per 100 Gallons	Infested Nuts
	Pounds	*Per Cent*
DDT (50% wettable powder)	6	3
Dieldrin (25% wettable powder)	2	5
Heptachlor (25% wettable powder)	4	3
Unsprayed	—	48

The second experiment was conducted in 1950 at Gustine in an orchard in which there was an abnormally heavy infestation. In a replicated set-up, treatments were applied to 6 Schley trees bearing a light crop, and to 4 Mahan trees with a heavy crop. The sprays were applied on August 23 and September 1 and 12. The first and second applications were well timed, but the third application was too late. Only two applications of dieldrin were made because the supply of this insecticide was short. Between the second and third applications records were made of the infested nuts on the trees. At harvest a sample of 250 nuts was examined from each tree that received the third application, and the results obtained are given in table 2.

No material was sufficiently effective for weevil control in such a heavy infestation. An additional application, between the second and third, might have improved the control obtained.

In 1951 an experiment was started at San Angelo. Each treatment was replicated on 5 Burkett trees and 1 of the Alexander variety. The weevil infestation was moderate. The adult weevils punctured the nuts while they were in the water stage of development. The trees were sprayed on August 16. On August 28–29 counts were made of weevil-punctured and sound nuts on the trees. The results of the examination of 100 nuts are given in table 3.

The discontinuance of the work made it impossible to complete the experiments and secure results at harvest.

Table 4.—Results of soil treatments for control of pecan weevil larvae, Brownwood, Texas, 1946.

Insecticide	Quantity per Acre	Larvae	
		Total	Dead
	Gallons	*Number*	*Per Cent*
Ethylene dibromide (10%)	20	243	68.0
	40	298	86.9
	Pounds		
BHC (5% gamma)	30	318	1.9
DDT (50% wettable powder)	30	309	0.4
None (average of two plots)	—	314	0.7

Soil Treatments.—Preliminary tests were made at Brownwood of several soil treatments for control of the weevil larvae. Soil blocks 2 feet square were used for each replicate, and the treatments were replicated nine times.

For the application of the ethylene dibromide a garden plow was used to make three furrows 6 inches apart and 6 inches deep in each block. The chemical was poured by hand, and soil was raked over the material with a hoe. DDT and BHC were mixed with water and poured over the top of the soil.

Approximately 50 larvae were placed in each soil block between November 2 and 10. Ants destroyed some of the larvae in certain blocks and a few larvae did not enter the soil. All the chemicals were applied on November 15. Between December 4 and 6 the soil was dug to a depth of 10 inches and examined to determine the effectiveness of the treatments. The results are given in table 4.

Ethylene dibromide was the only material tested that appeared worthy of further consideration.

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Smear EQ-335 to Kill Torsalo Larvae[1]

RALPH B. SWAIN[2]

Effective control of the torsalo fly, *Dermatobia hominis*, is being obtained in Nicaragua with 0.5-per cent toxaphene spray applied to animals at 15-day intervals. This treatment, however, operates only against the flies that carry torsalo eggs to the host animals and against the torsalo larva prior to its penetration of the skin of the host; the encysted parasite is not affected and may be expected to complete its development, leave the host, and pupate normally.

The advantages that would accrue from a treatment that would kill the torsalo larva in the host are obvious, both because it would give quicker relief to the infested animals and because it would reduce the time required for control by preventing the production of another generation of torsalo in the treated animals. At the suggestion of Dr. Ernest W. Laake, Research Advisor in Entomology, OFAR, a commercial formulation of Smear EQ-335, containing 3 per cent Lindane and 35 per cent pine oil, was tested in an experiment (Table 1).

Six torsalo-infested animals—three cows and three oxen—were used in the experiment. Tumors caused by the encysted larva on the left side of each animal received treatment; those on the right side were left untreated as checks. The location of each tumor was indicated on a map to permit an accurate examination at the end of the experiment one week later.

The smear was applied with a very stiff round brush 1½ inches in diameter; considerable pressure and a twisting motion was used in order to remove clotted blood and pus and to insure the entrance of some of the insecticide into the hole in the tumor. Some of the *Dermatobia* larvae reacted immediately to the treatment, exserting the posterior ends of their bodies from the tumors. Within a few hours many were leaving their hosts, presumably to die on the ground. A careful examination of each tumor was made 7 days after treatment. If the larva was still inside, it was extracted with forceps or by squeezing.

Table 1.—Results of treating torsalo tumors on six cattle with Smear EQ-335.

Animal	Tumors Observed		Status of Larvae After 7 Days					
			On Treated Side			On Untreated Side		
	On Treated Side	On Untreated Side	Not Found	Dead	Alive	Not Found	Dead	Alive
No. 1	12	8	11	1	0	1	0	7
No. 2	38	5	28	10	0	1	0	4
No. 3	3	20	0	1	2	5	0	15
No. 4	23	12	16	5	2	0	0	12
No. 5	18	2	16	0	2	0	0	2
No. 6	7	5	6	1	0	2	0	3
Total	101	52	77	18	6	9	0	43

Of the 18 dead larvae found after the treatment, 5 were in the first instar, 10 in the second, and 3 in the third. The degree of control obtained, calculated by Abbott's formula, was 93 per cent. It is thought that the larvae found still alive in the treated tumors had not actually come into contact with the insecticide. It was noted that of the treated tumors in which larvae could not be found, many were almost completely healed, with sound flesh closed over the breathing hole of the parasites.

Further tests to study the practicability of using Smear EQ-335, both alone and in combination with toxaphene spray, will be conducted in order to determine whether the time in which an infested herd can be rid of torsalo can be appreciably shortened.

ACKNOWLEDGMENTS.—The work reported was done with the cooperation and able assistance of Mr. Diosal Morales of the Nicaragua Ministry of Agriculture and Labor and Messrs. Orlando Lindo and Gonzalo Narvaez of the National School of Agriculture, Managua.

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[2] Entomologist, Office of Foreign Agricultural Relations, U. S. Department of Agriculture, assigned to the Servicio Técnico Agrícola de Nicaragua.

EDITORIALS

Bioassay of Organic Insecticides in Processed Foods[1]

The purpose of this editorial is to state clearly the advantages and disadvantages of chemical and bioassay methods for the detection of certain toxic organic insecticides in processed foods. Chemical methods are usually more accurate and specific then bioassay methods. On the other hand, biological methods of analysis are usually more sensitive than chemical methods. Steps considered necessary to improve the accuracy of the bioassay method will be indicated.

In the detection of spray residue in foods we are often interested in toxicity and not in the chemical composition of the residues. For this type of analysis bioassay methods are particularly suitable as a measure of toxicity and are not negated by mixtures of insecticides. Bioassay methods involving the use of mosquito larvae are important because of their high sensitivity and lack of specificity. There is a fairly close parallel between larval toxicity and mammalian toxicity, except for the pyrethrins and closely related compounds. The toxic residues of DDT, parathion, heptachlor, aldrin, dieldrin, chlordane, lindane, methoxychlor, and toxaphene also can be readily detected by mosquito larval tests. With parathion, for example, it is possible to detect by bioassay concentrations as low as 0.0005 p.p.m. in the final test solution. Most of the other insecticides give complete kills at concentrations of 0.1 to 0.01 p.p.m.

Excess of fats in foods will smother the larvae and increase the apparent toxicity, while smaller amounts may selectively extract the toxicant from the solution and thus reduce the apparent concentration of toxicant. In order to overcome this it is necessary to remove the fatty materials when they are present in large amounts. Methods for doing this have not been completed but work is in progress on solvent combinations that give satisfactory separation in some cases. In addition to fats, organic acids and alkaloids may also interfere. Attention should be given to the extraction of these substances by basic or acid solutions.

With certain insecticide compounds it is difficult to distinguish between dead and living larvae, and individual counts may vary thus leading to different interpretations of the results. This can be partly overcome by using a larger number of larvae, but better technique for counting would first be necessary. There is a definite limit as to the number of larvae that can conveniently be counted, particularly if a large proportion survive because of the rapid movements of the larvae.

In conclusion, it should be stated that better methods for the detection of organic spray residues in processed foods are urgently needed. Bioassay is perhaps the only generally acceptable means available for the detection of spray residues in mixtures of organic insecticides in processed fruits and vegetables. It can be used also for the detection of toxic residues of a single compound, but analytical chemical methods are making rapid progress from this approach. Limitations of the bioassay involving the use of mosquito larvae include the number of larvae per test, counting methods, and the removal of interferences by selective extraction. The attention of the reader is called to these limitations with the view of stimulating greater interest which it is hoped will result in the improvement of the bioassay.

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Entomology in the Point Four Program[1]

EDSON J. HAMBLETON, *Office Foreign Agricultural Relations, U.S.D.A.*

Most of us assembled here today are primarily concerned with entomological research and control as they are related to our own domestic problems of food production and health protection. Nevertheless, it is gratifying to know that your program committee has seen fit to allot time for a discussion of the role entomology is now playing in the program of technical cooperation in the underdeveloped nations of the world—the program that has come to be known as Point Four.

Point Four is sometimes referred to as a "give-away" program. But it is not that. It is just a simple way of helping people help themselves. Point Four does not operate where it is not wanted. Every Point Four project grows out of a request from a foreign government. Each project then develops as a result of a cooperative agreement between the Technical Cooperation Administration in the United States and the country making the request. Personnel, funds, equipment, and other contributions are all specified in the agreement. The recipient country contributes the equivalent of three dollars for every American Point Four dollar that is spent.

Eighty per cent of the Point Four work falls into one of three categories: food, health, or education. The most urgent of these is food. Therefore, Point Four administrators are concentrating first on helping people grow more food. At the same time they are teaching them how to wipe out disease and how to establish schools and train teachers. In the short period Point Four has operated, marked progress has already been made; but the program must be considered a long-term proposition if best results are to be accomplished.

In a recent address, W. Averell Harriman simply stated the basic purpose of all agricultural projects under Point Four: "We Americans, with our scientific knowledge, are literally helping grow two ears of corn where one grew before." You and I, as entomologists, know that this is possible in any underdeveloped country where certain changes can be easily introduced—changes such as improved seed, better preparation of the soil, use of fertilizers and pesticides, and adoption of more effective agronomic practices.

Some noteworthy examples of increased yields have already been reported by Point Four workers. In one area of India the yield of potatoes has been increased from 119 bushels per acre to 235, and the yield of wheat from 13 to 26. In El Salvador, corn yields have been doubled. Yet if we are to carry on and bring about other increases in farm products, we must not lose sight of the fact that we will have to provide facilities for proper handling and storing of food. If we do not, we will be growing two ears of corn where one grew before just to feed twice as many weevils!

We entomologists are conscious of the fact that as crop production is improved, conditions are also brought about that are likely to favor destructive insects and to provide them with better means of becoming a constant menace. This fact should not be overlooked as we go forward in our technical assistance planning. Few farmers in the underprivileged areas of the world have any conception of the losses that result from insect attack. And even if they do, there has been little that they could do to fight back. I have always felt that, if we could find ways and means to protect from insects and diseases the crops *now* being grown, that alone would increase production to the point where we would no longer need to fear food shortages.

Although most underdeveloped countries have tropical or subtropical climates, their insect problems are much like ours. They are confronted with many of the cosmopolitan species that have been widely distributed through commerce for many centuries. Among them are some of the most annoying and dangerous to man and most destructive to his livestock, crops, and food products.

The amount of insect control practiced by peoples in these countries is more or

[1] Paper read by Edson J. Hambleton, Field Service Consultant in Entomology, Office of Foreign Agricultural Relations, United States Department of Agriculture, before 36th annual meeting of the American Association of Economic Entomologists, Santa Barbara, California, June 24–26, 1952.

less proportionate to the kind of agriculture they carry on. In countries that have progressed in their agriculture, for instance, one will find some kind of organization with well-trained technicians. Too often, however, both the technicians and the necessary government support is wanting. Often, good conscientious workers are hampered by lack of funds, equipment, or transportation facilities and cannot do justice to their work. Handicaps like these, the customs of the people, their prejudices and beliefs—all combine to keep many a good worker confined to his office or laboratory. Progress in applied entomology cannot advance in a set-up of this kind.

We in the United States are noted for our organization, our institutions, our eagerness to do things in a big way. We are great competitors, yet, in the interest of a common cause, we manage to work together. As new problems arise, we tackle them to the best of our ability. We are forever trying to improve this or that, devise short-cuts, develop labor-saving devices. Most of us take for granted the opportunities that our country has offered us for the development of our entomological organization—opportunities that have enabled us to make it the most practical entomological organization in the world. We need only to travel to almost any foreign country to begin to understand and appreciate the service that this organization has given to agriculture and general welfare in the United States.

In practically all branches of entomology, we have learned that other countries can be a source of inspiration to us. They have cooperated with us when we have gone abroad in search of parasites and predators of our insect enemies. Until World War II, however, our entomological contact in foreign areas—except for cooperative efforts between ourselves and the neighboring countries of Canada and Mexico—have been pretty much limited to this field of activity and to the problems of international nomenclature. During the war we found many opportunities to assist other countries in insect control; for instance, we were obliged to control bedbugs, lice, and mosquitoes to protect our own troops. It is very doubtful whether we would have taken the initiative to offer such protection to the natives of the South Pacific or elsewhere had we not been in the conflict ourselves.

Programs of international cooperation in pest control have been greatly stimulated as a result of the war and the position the United States has assumed in world leadership. Fortunately most of the other countries realize and accept the progress we have made as a matter of fact. They look forward to receiving our guidance and help in many fields, and we have much to offer. Our institutions and experiment stations, our State and Federal Governments, and our technical workers have the results of research to share, enabling workers of other lands to utilize our ideas and practical field experiences in insect control. The fact that we are recognized as leaders in economic entomology is an added reason why we should participate in international programs. Besides, as we in America become more and more dependent upon foreign countries to supply our strategic needs, it is only logical that we reciprocate by making available to them not only our manufactured goods but some of our know-how as well. Our problems of mutual interest and importance must be worked out cooperatively if we are to preserve and conserve the resources of the world.

I am convinced, therefore, that entomology can and should play a more active part in any Point Four program designed to increase the production of food. If entomology is to have its proper role, we will have to make every effort, both as individuals and as organizations, to influence those concerned with the planning of the Point Four program. The authorities of the recipient Point Four country must be informed and convinced of the need for insect control so that requests for technical assistance can be made and agreed upon in time for control programs to do the most good.

The history of conquering agricultural pests in the United States is filled with lessons for the entomologist abroad. They teach him such things as what pests to expect, what control methods to use, what pitfalls to avoid. They show him the importance of being foresighted about such matters as quarantine.

But agricultural pests are not the only ones that harass the world. For many years we have suffered from infectious human diseases that are insect-borne and by that means have been imported from

one place to another. Yellow fever and malaria are good examples, both carried from victim to victim by mosquitoes. Everywhere, the problems of health and agriculture go hand-in-hand. Although in most countries medical science has advanced more rapidly than entomology, it is only in recent years that an attempt has been made to control some of the pestilential diseases that still sweep through large areas of the world in epidemic waves. Vast areas of the world remain undeveloped and their resources are denied to mankind because of diseases that are rampant. These must be controlled if economic development is to succeed. Health authorities, like entomologists, are concerned with quarantines, which have served a useful purpose in preventing the spread of disease from country to country. The development of faster means of transportation, however, is limiting the effectiveness of quarantine protection; and attention is now being given to regional programs designed to attack and eradicate certain diseases at their source. This is a most constructive approach in the international health movement of today, in which collaboration toward a common goal has been really magnificent.

The World Health Organization of the United Nations came into existence in April 1948. Its membership includes at least 70 nations. Its objectives and scope of activity are far-reaching. The United States looks to this organization for leadership and guidance even though it is prepared to extend itself beyond the World Health Organization in its bilateral programs. Our first efforts in bilateral cooperation in health began nearly 10 years ago, when a program was launched by the Office of the Coordinator of the Inter-American Affairs in 18 republics of Latin America. Major emphasis has been given to controlling insect-borne diseases such as malaria, typhus, and plague. During this period the threat of yellow fever has been greatly reduced in the Western Hemisphere by the Pan American Sanitary Bureau, which acts as the Health Organization's regional office for the Americas. Its campaign to eradicate the yellow fever mosquito *Aëdes aegypti* (Linn.) is having noteworthy success.

One of the biggest tasks that lay ahead when the program of economic aid to Greece and Turkey was initiated in 1947 was the control of malaria. So successfully was it carried out that the disease, once a major problem in Greece, is now of minor significance. Throughout the Middle East and South and Southeast Asia malaria-control projects have included extensive DDT residual spray operations and the distribution of chloroquinine. Hundreds of thousands of dwellings of one kind or other have been sprayed in an effort to relieve the suffering of the people. American experts supervise these malaria control teams; they train workers and provide technical guidance and assistance to governments in developing adequate health services. In Iran alone last year 15,600,000 square meters of building surfaces were covered with a residual DDT spray, in a campaign that extended to towns and villages with a total population of nearly 450,000. In Pakistan, a malaria-control project that has been running for two years not only has brought about a drastic reduction in the malaria rates but at the same time has substantially improved the health and vigor of agricultural laborers and increased their productivity. As a result of control operations, a marked increase in agricultural output always occurs. The story is almost the same in all areas where this good work is being waged.

Cooperative effort in the control of agricultural pests has received less attention in technical assistance programs than has that of insect vectors of human diseases. This fact is easily understood, yet it in no way reflects the urgent need to wage all-out war on some of the pests that plague livestock and food and fiber crops in so many areas of the world that they are a matter for international concern. However, within the last few years, I am pleased to report, technical assistance administrators are viewing insects and the damage they cause in a new light. They are beginning to focus attention on losses caused by insects in terms of food production and to see how insect control projects might form an integral part in programs of technical collaboration. Entomology can and will play a more important part in technical assistance if given the opportunity. Fortunately it has already clearly demonstrated its value.

During the last 10 years the United States Deparment of Agriculture and the ministries of agriculture in half a dozen

countries of Central and South America have conducted joint programs of technical cooperation. This work is now a part of the Point Four program, supervised by the Technical Cooperation Administration of the Department of State. Entomological assistance has been provided these countries by giving technicians specific assignments on a short-term basis. They have aided on such problems as the migratory locust; livestock pests; insects affecting cotton, coffee, citrus, and lemon grass; insects that plague stored grain; and insects that carry human diseases.

Within the same period the Food and Agriculture Organization of the United Nations has sent experts to many parts of the world, particularly to Latin America and the Middle East. Their entomologists have studied grain-storage practices and have gathered and publicized facts about the losses caused by insects and other pests that invade inadequate storage facilities. FAO has estimated that in a single year the losses caused by rats, insects, and fungi to stored grains and rice alone totaled about 33 million tons in the world's granaries. This is enough food to keep 150 million people alive for a year. Cutting down these losses through modern techniques of storing and handling food supplies has been one of FAO's major problems ever since its establishment. FAO's assistance has led to the construction of safe storage facilities in several countries, thereby helping to eliminate the heavy losses from insects.

But grains are not the only crops that need protection. Livestock also suffer from insect pests. Raising livestock is one of the chief activities in most Latin American countries and is essential to their economy and well being. In Colombia alone there are more cattle than people. Two of the most serious cattle pests in the southern hemisphere range all the way from Mexico to Brazil. These are the cattle tick, *Boophilus annulatus* var. *microplus* Can., and the human bot or torsalo fly, *Dermatobia hominis* (L. Jr.). No loss figures are available, but we know that the losses caused by these pests to hides, and to beef and milk production are tremendous. Mortality among calves may be as high as 70 per cent in some of the more heavily infested areas of Central America.

Until the advent of DDT and other chlorinated hydrocarbon insecticides, livestock producers relied entirely upon arsenical dips for tick control. In recent years these materials have not been responding well and specialists have expressed the belief that the cattle tick has developed some resistance to arsenicals. For the torsalo fly, no solution had ever been found to combat either the fly or its grub, which lives under the animal's hide.

In 1948 a U. S. Department of Agriculture entomologist went to Brazil under the auspices of the American International Association for Economic and Social Development to test several of the new insecticides and rotenone on the control of livestock pests. Several months after he had left Brazil, it was discovered that wherever applications of a 0.5-per cent toxaphene emulsion concentrate had been continued for a period of five months, there was a noticeable decrease in the incidence of torsalo warbles. There was no experimental evidence to the effect that toxaphene was toxic to either the young grubs as they entered the hide or to the encysted older grubs, but it was the general belief that the residual toxaphene was killing off the flies and mosquitoes that serve as vectors for the eggs of the female Dermatobia.

On the basis of these developments, Point Four technicians in February 1950 set up toxaphene-spray demonstrations in Nicaragua and Ecuador. They found that in 8 months treated animals gained an average of 139 pounds more than the untreated. They also found that Dermatobia could be satisfactorily controlled by eliminating its dipterous vectors; at the same time ticks and several species of other miscellaneous flies were likewise affected.

Wherever this work has been demonstrated, enthusiasm reigns throughout livestock circles of Latin America. Both large and small producers, both individually and collectively, have started campaigns. The Ministries of Agriculture of Costa Rica, Nicaragua, Panama, and Ecuador are developing their own services and lending support to cooperating agencies working to bring these pests under control. The success of this work has led to the development of a full-time regional project in Central America and northern

South America. The entomologist assigned to the project has completed one year's work in Costa Rica and is now preparing to carry on similar work in Ecuador and the other countries. He has emphasized tick and torsalo control and has helped train native technicians, extension workers, and farmers in practical and safe methods of treating livestock for parasite control.

Point Four entomologists are now stationed in El Salvador, Nicaragua, Bolivia, and the Dominican Republic, and will soon be sent to Ecuador, Peru, and Brazil. These men are being confronted with the varied insect problems of cotton, coffee, citrus, corn, tobacco and other miscellaneous crops and livestock. They conduct research, train local assistants in the fundamentals of entomology and the use of insecticides, and carry on extension activities. They are accumulating a wealth of information on the local flora and fauna, which until now have been too little understood for even our own needs in the United States and still await further exploration in many fields. This cooperation is a challenging experience that is rapidly paying dividends in an improved agriculture at the same time that it is stimulating the interest of United States industry in exporting insecticides and spray and dusting equipment.

A move is now on to set up a regional project in Panama for introducing, propagating, and distributing parasites and predators of crop pests, especially pests that affect sugarcane, coffee, corn, cotton, coconuts, fruits, and vegetables. This would be a cooperative project involving the U. S. Department of Agriculture, the Panamanian Ministry of Agriculture, and the Technical Cooperation Administration. Considerable attention would also be given to developing cultural methods for insect control and to other practices that would tend to minimize the need for insecticides.

A laboratory established near the Panama Canal would serve as an advance post for the entire Western Hemisphere. It would reduce the probability that new insect pests would be introduced as a result of commerce through the Canal.

In the Eastern Hemisphere Point Four aid in the control of agricultural pests has been confined largely to an attack on the desert locust, *Schistocerca gregaria* (Forskal). Entomologists are now being recruited for India, Iran, and Iraq for general entomological and extension work. Point Four entomologists are already on duty in Liberia and the Philippines.

A recent achievement unprecedented in the long history of fighting the desert locust clearly indicates how modern techniques can be applied successfully in the program of technical cooperation with other governments. Following a request from the Government of Iran in April 1951 for assistance in the Iranian anti-locust campaign, the United States quickly despatched by air 8 small spray planes, 10 tons of aldrin, 8 pilots, and 2 entomologists to the scene of activities in southern Iran. Within 3 months, some 53,700 acres were sprayed in 18 widely separated localities. The significance of these operations had far-reaching effects when it was proved that aldrin, applied at the rate of 1.72 ounce per acre, would control the desert locust and that the material could be applied by plane, a method hitherto untried in any country infested by this locust.

Iran, like several other countries in the Near East, has an efficient organization for locust control, but the infestation in 1951 was too large for that country to cope with alone. That was why it requested help from the United States, as well as from Great Britain and Russia. Point Four's mobile air unit, cooperating with Iran's ground control organization, solved the problem in time to prevent major crop losses. The project demonstrated new methods and new techniques that have pointed the way to better international cooperation in a fight against an enemy that has plagued the Near East since Biblical days.

The effectiveness of aerial spray operations in Iran immediately prompted Pakistan and India to request identical assistance from the United States last summer. In similar demonstrational work in those countries, 16,600 acres were sprayed in Pakistan and 5,300 in India. In Pakistan it was discovered that oil diluents were not required for the aldrin concentrate, but that water would do just as well—and for much less money.

Before the outbreak of locusts in 1951, the Food and Agriculture Organization had made some progress toward international coordination of locust control

efforts in both the Near East and in Central America. FAO, however, was unable to contribute financially or in any other material way to the existing control programs. The impact of last season's work by Point Four stimulated interest in and threw a new light on the locust problem throughout the entire infested area. In October 1951, FAO called a meeting in Rome, inviting technicians from desert locust-infested countries. A Technical Advisory Committee on Desert Locust Control was established. Its membership includes Egypt, France, India, Iran, Pakistan, the United Kingdom, and the United States. One of its chief purposes is to explore avenues of mutual aid and of international assistance. The Committee held its first meeting in Rome in March 1952. By that time a regional project had already been set up and approved by Point Four, which provides for small spraying planes and insecticides to be used under the supervision and direction of a United States entomologist, who, as Project Director, is also the United States representative to the FAO Committee. The technical aid would be administered under bilateral Point Four agreements with countries in the desert locust area.

At the Rome meeting in March, FAO proposed to provide additional aid in the way of supplies, equipment, and insecticides for locust control, aid that was to be given under the direction of the FAO Committee and under bilateral agreements with member nations. The Committee agreed upon a system of priorities for supplies and equipment and the manner in which control activities would be worked out from country to country.

Point Four is authorized to provide locust control aid only upon request from, and under bilateral agreement with, individual countries. The purpose of its locust control program is to assist locust-infested countries by supplementing local control activities by demonstrating aerial spraying methods and by training local pilots how to fly and operate spraying planes. The United States program is thus coordinated with the FAO programs; to avoid overlapping of work, technicians of the British and local control units are cooperating with others in the field. FAO in Rome serves as a clearing house for all national and international locust-control activities.

Iran today is the scene of a seven-country program which will probably go down in history as one of the finest examples of international cooperation in pest control. There India, Pakistan, Turkey, Italy, Russia, and the United States are cooperating by supplying insecticides, bran, spray equipment, trucks, jeeps, and planes. In addition, the United States is supplying technical knowledge, furnishing two entomologists and the pilots who fly the planes.

The locust control in Iran began after operations had been under way in Iraq and Jordan for nearly two months. Swarms of locusts moving northward from the Arabian Peninsula have fanned out through the Kuwait Province, Iraq, and into Jordan. These have joined escapees of the past season to cover large areas in Iran and Pakistan. Although the situation is critical and the task a tremendous one, every effort is being made to win the fight. Preparations are being made to continue the fight into Pakistan, India, and Afghanistan during the summer. By fall, control work will probably be undertaken in Yemen, Ethopia, and, possibly, the Arabian peninsula.

This marvelous project is accomplishing more than killing locusts. It is warding off starvation. It is instilling confidence in people with whom we have had little contact in the past. It is making friends and good will for us. It is proving that cooperation among nations is vital even when it comes to protecting farm crops from insect plagues. This insect control project is a typical example of how the United States through its Point Four program is interested in helping other nations without jeopardizing in any way the individual responsibilities of each nation.

RETROSPECT AND PROSPECT

With the advent of the new year, this Association, as such, will pass into history. We are in a period of bigger and we hope better things. Mere size is easy to attain. Too much starch and too little exercise does the trick for the human. All sorts of motivations lead to membership in this Association that has stood for over 60 years as the only refuge of the man who has attempted to make life more bearable and abundant through applied entomology. To some the name "Economic Entomologists" has carried a stigma, to others a sense of limitation, but to the vast majority it has stood as the beacon that has guided their thoughts and aspirations.

With the increase in membership to be brought about by the inclusion of the nonduplicated memberships of the Entomological Society of America, we must necessarily embark upon further departmentalization of the organization, its functions and its publications. Herein lies the greatest danger to the usefulness of the organization. There has been a growing tendency to departmentalize within the Association that has been difficult to neutralize. In the new "Society" the tendency will be even greater with taxonomists, morphologists, physiologists, etc. desiring sections or groups where they may present their findings to others with mutual interests and understanding. Such multiplication of sections will tend to divorce the worker from the general over-all purpose of the Society and certainly will lead to narrow channeling never contemplated or practiced by the leaders of the past.*

The greatest value of the American Association of Economic Entomologists has been the inspiration of the great leaders of the past to the young entomologists who have had the opportunity to hear them discuss the broad aspects of economic entomology. In order that the new "Society" may continue to inspire, the new leaders must plan carefully to keep the major portion of the annual and branch meetings at the level of general interest. Every effort must be made to integrate the work of the applied entomologist, backed of course by the knowledge of the taxonomist and physiologist, with other sciences, such as chemistry, phytopathology, medicine and engineering. This can be accomplished by expanding the general sessions to include such sciences and encouraging the special groups to work out conferences and round tables for the development of their own specialties. Such special conferences may be scheduled on occasion at other times and places than at the annual meeting. The principle that every entomologist should have equal opportunity to present the results of his research must be kept as a cardinal right to encourage the development of young men. But they should also be encouraged to listen to those capable of presenting the broader aspects of entomology rather than to confine their attention to their own special interests.

The principal reasons for the consolidation is to be able to present a unified front in times of national emergency; to have a single force speaking for all entomologists before scientific gatherings and to develop in the minds of the public a realization that entomology is an essential part of the national economy and culture. The consolidation should further these aims and at the same time "promote the science of entomology in all its branches."

EARNEST N. CORY

With the passing of the American Association of Economic Entomologists, the publication of the names of the entomologists who have served as president together with the date and place of the anual meetings should serve a useful historical and inspirational purpose.

EARNEST N. CORY

* Elsewhere in this JOURNAL is the list of past presidents.

MEETINGS AND PAST PRESIDENTS

AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

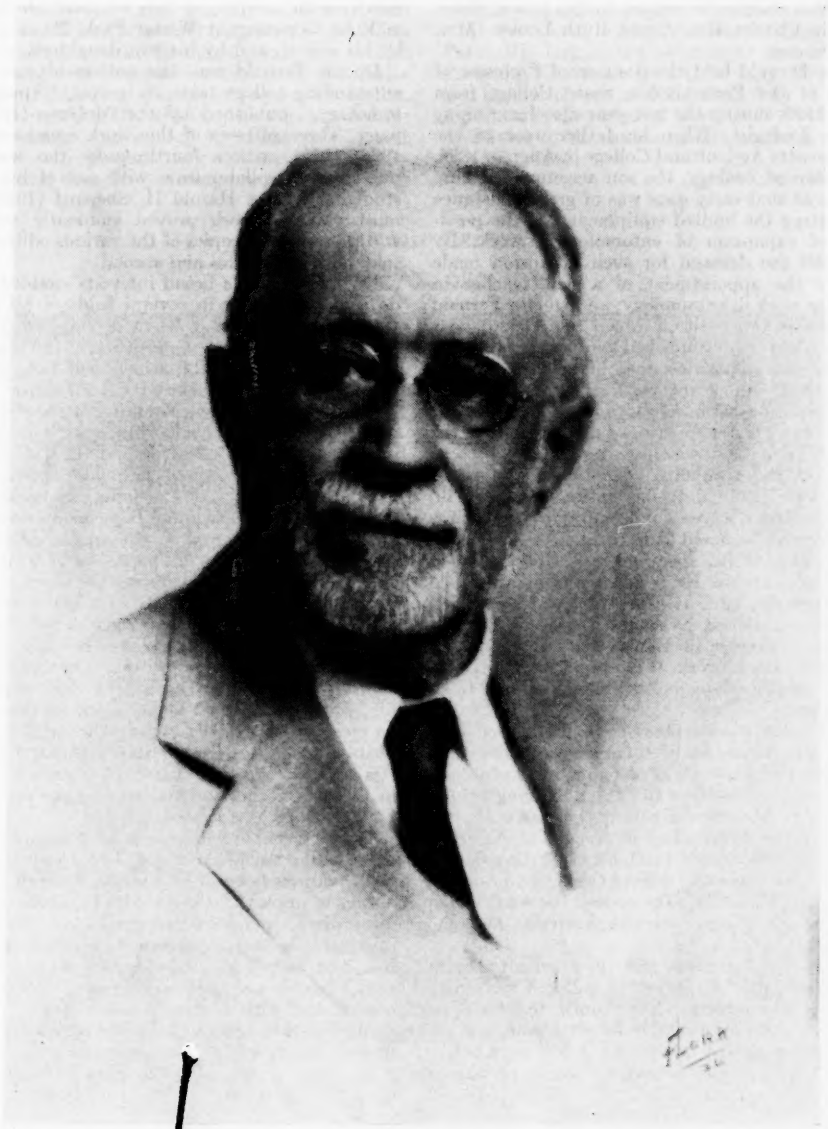
No.	*President*	*Date*	*Place*
1	C. V. Riley	Nov. 12–14, 1889	Washington, D. C.
2	C. V. Riley	Nov. 11–13, 1890	Champaign, Ill.
3	James Fletcher	Aug. 17–18, 1891	Washington, D. C.
4	J. A. Lintner	Aug. 15–16, 1892	Rochester, N. Y.
5	S. A. Forbes	Aug. 14–16, 1893	Madison, Wis.
6	L. O. Howard	Aug. 14–15, 1894	Brooklyn, N. Y.
7	John B. Smith	Aug. 27–28, 1895	Springfield, Mass.
8	C. H. Fernald	Aug. 21–22, 1896	Buffalo, N. Y.
9	F. M. Webster	Aug. 12–13, 1897	Detroit, Mich.
10	Herbert Osborn	Aug. 19–20, 1898	Boston, Mass.
11	C. L. Marlatt	Aug. 18–19, 1899	Columbus, Ohio
12	Lawrence Bruner	June 22–23, 1900	New York, N. Y.
13	C. P. Gillette	Aug. 23–24, 1901	Denver, Colo.
14	A. D. Hopkins	June 27–28, 1902	Pittsburgh, Pa.
15	E. P. Felt	Dec. 26–27, 1902	Washington, D. C.
16	M. V. Slingerland	Dec. 29–31, 1903	St. Louis, Mo.
17	A. L. Quaintance	Dec. 29–30, 1904	Philadelphia, Pa.
18	H. Garman	Jan. 1–4, 1906	New Orleans, La.
19	A. H. Kirkland	Dec. 28–29, 1906	New York, N. Y.
20	H. A. Morgan	Dec. 27–28, 1907	Chicago, Ill.
21	S. A. Forbes	Dec. 28–29, 1908	Baltimore, Md.
22	W. E. Britton	Dec. 28–29, 1909	Boston, Mass.
23	E. D. Sanderson	Dec. 28–29, 1910	Minneapolis, Minn.
24	F. L. Washburn	Dec. 27–29, 1911	Washington, D. C.
25	W. D. Hunter	Jan. 1–3, 1913	Cleveland, Ohio
26	P. J. Parrott	Dec. 31–Jan. 2, 1914	Atlanta, Ga.
27	H. T. Fernald	Dec. 28–31, 1914	Philadelphia, Pa.
28	Glenn W. Herrick	Dec. 27–30, 1915	Columbus, Ohio
29	C. Gordon Hewitt	Dec. 28–30, 1916	New York, N. Y.
30	R. A. Cooley	Dec. 31–Jan. 2, 1917–18	Pittsburgh, Pa.
31	E. D. Ball	Dec. 26–27, 1918	Baltimore, Md.
32	W. C. O'Kane	Dec. 31, 1919	St. Louis, Mo.
33	Wilmon Newell	Dec. 29–31, 1920	Chicago, Ill.
34	George A. Dean	Dec. 28–31, 1921	Toronto, Canada
35	J. G. Sanders	Dec. 28–30, 1922	Cambridge, Mass.
36	A. G. Ruggles	Dec. 29, 1923–Jan. 2, 1924	Cincinnati, Ohio
37	A. F. Burgess	Dec. 31, 1924–Jan. 3, 1925	Washington, D. C.
38	H. A. Gossard	Dec. 29, 1925–Jan. 1, 1926	Kansas City, Mo.
39	Arthur Gibson	Dec. 28, 1926–Jan. 1, 1927	Philadelphia, Pa.
40	R. W. Harned	Dec. 27–30, 1927	Nashville, Tenn.
41	W. B. Herms	Dec. 27–31, 1928	New York, N. Y.
42	T. J. Headlee	Dec. 30, 1929–Jan. 2, 1930	Des Moines, Iowa
43	Franklin Sherman	Dec. 29–Jan. 1, 1931	Cleveland, Ohio
44	J. S. Houser	Dec. 29–31, 1931	New Orleans, La.
45	W. P. Flint	Dec. 29–30, 1932	Atlantic City, N. J.
46	W. E. Hinds	Dec. 27–29, 1933	Boston, Mass.
47	E. F. Phillips	Dec. 27–29, 1934	Pittsburgh, Pa.
48	L. A. Strong	Dec. 30, 1935–Jan. 1, 1936	St. Louis, Mo.
49	L. S. McLaine	Dec. 28–31, 1936	Atlantic City, N. J.
50	F. C. Bishopp	Dec. 27–31, 1937	Indianapolis, Ind.
51	J. J. Davis	Dec. 26–30, 1938	Richmond, Va.
52	E. R. Sasscer	Dec. 27–30, 1939	Columbus, Ohio
53	H. S. Smith	Dec. 27–31, 1940	Philadelphia, Pa.
54	Harry B. Weiss	Dec. 29, 1941–Jan. 1, 1942	San Francisco, Calif.
55	P. N. Annand	Scheduled for New York Dec. 29–31, 1942	New York City—cancelled
55		Dec. 7, 8, 9, 1943	Columbus, Ohio
56	E. O. Essig	Dec. 13–15, 1944	New York City
57	D. L. VanDine	Dec. 3–6, 1945	Dallas, Tex.
58	Clay Lyle	Dec. 9–12, 1946	Richmond, Va.
59	Ernest N. Cory	Dec. 27–30, 1947	Chicago, Ill. with AAAS
60	S. A. Rohwer	Dec. 13–16, 1948	New York City
61	A. M. Boyce	Dec. 13–16, 1949	Tampa, Fla.
62	C. P. Clausen	Dec. 18–21, 1950	Denver, Colo.
63	R. E. Campbell	Dec. 10–13, 1951	Cincinnati, Ohio
64	E. F. Knipling	Dec. 15–18, 1952	Philadelphia, Pa.

Summer meetings held:

Aug. 9–10, 1910—Berkeley, California

June 22–23, 1932—Chicago, Illinois

OBITUARIES



Henry Torsey Fernald

The recent passing of Doctor Henry Torsey Fernald brought to a close one of the outstanding epochs in the history of entomology. For a period of sixty-six years, beginning in 1886 when his father, the late Professor Charles Henry Fernald came to the Massachusetts Agricultural College (now the University of Massachusetts) to teach the first formal course in entomology at the institution, to the present year, there has been an unbroken period of service to the University by father and son, active and emeritus.

Doctor Fernald was born on April 17, 1866 in Litchfield, Maine, where his father was principal in the Litchfield Academy. He was the son of Charles Henry Fernald and Maria Elizabeth (Smith) Fernald, both of whom were internationally known for their work in entomology. With such a background it was natural that the son and only child should become thoroughly imbued in the science and should decide to make it his own life work. Between 1871 and 1886 the family resided in Orono, Maine, where the elder Fernald was on the staff of the Maine State College, and the son attended the local schools and the College, receiving the B.S. degree in 1885 and the M.S. in 1888. Doctor Fernald then entered Johns Hopkins University, receiving the Ph.D. degree in 1890. His dearest friend at Hopkins was the late Doctor Charles Edmund Simon, through whom he became acquainted with the latter's sister Minna R. Simon,

to whom he was married on June 9, 1890, in Baltimore. Three children were born to this union, Helen Elizabeth, Charles Henry, and Ruth Louise (Mrs. Carl B. Stone).

Doctor Fernald held the position of Professor of Zoology at the Pennsylvania State College from 1890 to 1899, during the last year also functioning as State Zoologist. When his father went to the Massachusetts Agricultural College in August, 1886, as Professor of Zoology, the son accompanied him, and even at that early date was of great assistance in evaluating the limited equipment and the possibilities of expansion of entomological work. By June, 1899 the demand for such expansion made necessary the appointment of a new teacher to handle the work in entomology, and Doctor Fernald was named to this position. A separate Department of Entomology was established and he took charge as a full professor, a position that he held for the succeeding thirty-one years. Between 1902 and 1918 he also held the position of State Nursery Inspector. From 1913 to 1927 he functioned as Chairman of the School of Science at the College, resigning to become Director of the Graduate School, which position he held from 1927 until his retirement in 1930. During the last few years preceding his retirement, Doctor Fernald suffered from asthma, which condition necessitated his spending the winter months in a warmer climate. He selected Florida and lived first at Orlando, later at nearby Winter Park. Following his retirement he established his home and permanent residence in Winter Park. Here he accomplished much work in entomology until his physical condition became such that this had to be relinquished.

Virtually all honors possible in his chosen field came to him during his lifetime. He was a long-time member of the Association of Economic Entomologists, serving as President in 1914, and being elected an Honorary Member. Similarly, he was a charter member of the Entomological Society of America, to which he was elected to Honorary Fellowship in 1937, and was chosen to deliver the Annual Address in 1927, in Nashville, Tennessee. He was also a member of many other scientific societies, at home and abroad.

Doctor Fernald remained in excellent health until he was past 80, when he suffered a decline, though very gradually. Even until the last few weeks of his life he was able to get about, and remained active almost to the end. A few days before his death he suffered recurring attacks of angina that became more and more severe, causing his death on the morning of July 15, 1952. He is buried in Palm Cemetery at Winter Park. He is survived by his widow, and by his two daughters.

Doctor Fernald was the author of one of the outstanding college texts on insects, "Applied Entomology," published by the McGraw-Hill Company. Three editions of this work appeared (1921, 1926, 1935), with a fourth under the same title published in collaboration with one of his former students, Doctor Harold H. Shepard (1942). This most valuable work proved eminently successful and thousands of copies of the various editions were sold, both in America and abroad.

Doctor Fernald's broad interests enabled him to do important work in several fields of his science. In applied entomology he made important studies on various insecticides, particularly the arsenicals, including lead arsenate, which had been first developed at the Massachusetts Agricultural College in 1892 by the late F. C. Moulton. Studies on various insect pests of local importance were made, such including the San José scale and the codling moth. In systematic entomology he made a special study of the digger wasps of the family Sphecidae (Hymenoptera) in which group he became a recognized authority, particularly on the species of the New World, and on which he published several papers. In the course of these latter studies he visited many of the leading museums, both in North America and in Europe (1913), where he made detailed observations on the types of the species described by earlier authors and made copious notes on other species in the same collections. During the later years of his life, when he could no longer work on these wasps, he presented his collection, together with his manuscript notes, to the United States National Museum. His general collection of insects, together with that made by his father and mother, was presented to the University of Massachusetts.

Doctor Fernald will always be remembered as an outstanding teacher. He possessed a vast knowledge of the various fields of his science, and had a marked ability to impart this knowledge to others. He had a most placid and unruffled disposition that proved invaluable in such a profession. To those who knew him best he will long be remembered as one of the most kindly and patient of men, thoughtful of others, and with a great sense of humor. His students and colleagues will always be grateful for the understanding and encouragement he gave to them.

CHARLES P. ALEXANDER

Melville Thurston Cook

Sept. 20, 1869-Aug. 11, 1952

In the early days of the development of scientific agriculture in the United States, when some exceptional individuals could justly claim competence in both Economic Entomology and Plant Pathology, a young professor at DePauw University, Dr. Mel. T. Cook, was chosen by Mr. F. S. Earle, the first Director of the Agricultural Experiment Station at Santiago de las Vegas, Habana, Cuba, to head its Department of Vegetable Pathology. Assisted by Wm. T. Horne, subsequently Plant Pathologist at Riverside, California, several publications under their joint authorship were issued between 1904 and 1907 on the insects and diseases of tobacco, coffee, oranges, vegetables, corn and sugar-cane which are still fundamental as early records of the pests of those crops. Dr. Cook not only took an active part in the early development of tropical economic entomology, but he joined the American Association of Economic Entomologists, apparently in 1905, and retained his membership until the very end. For many years, however, he has had his copies of the JOURNAL OF ECONOMIC ENTOMOLOGY sent to the Library of DePauw University.

Dr. Cook's principal later contribution to entomology was, while at the Experiment Station at Río Piedras (1923–1940), in keeping alive during its darkest days the Journal of the Department of Agriculture of Porto Rico. Now re-named the Journal of Agriculture of the University of Puerto Rico, it proudly claims the record of longest con-

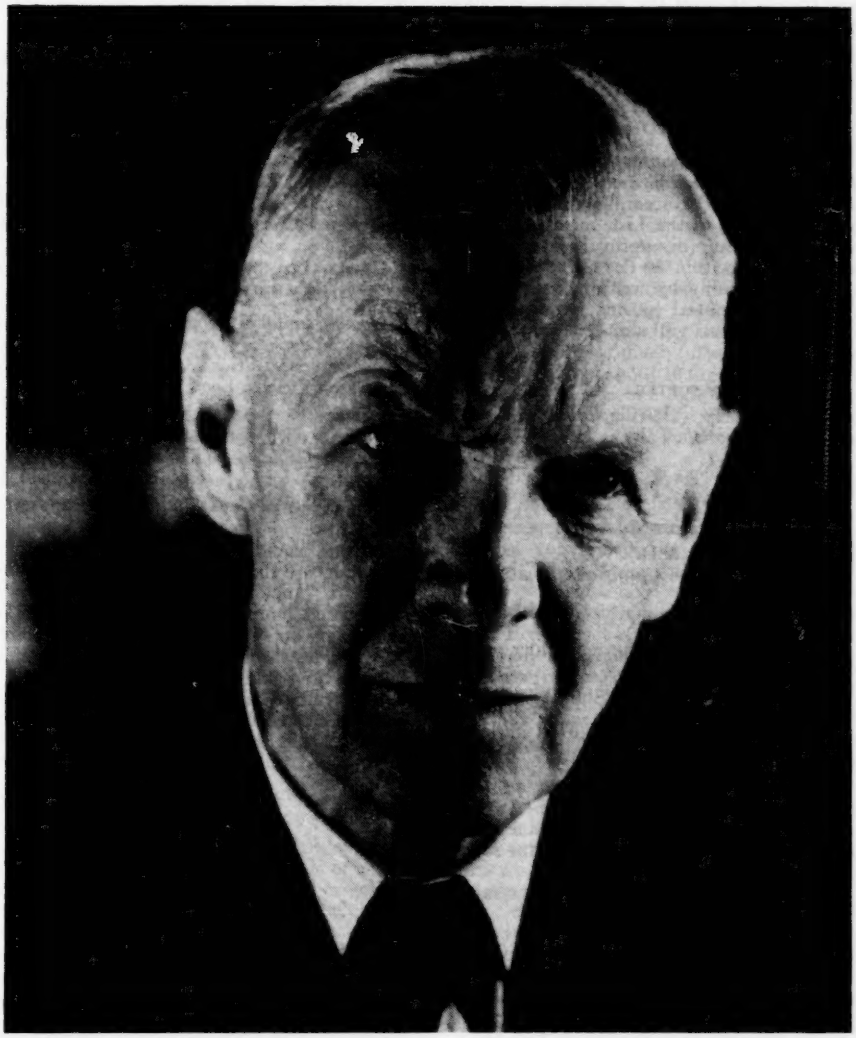
tinuous publication of any in Latin-American agriculture. While Dr. Cook was Editor, it was (and continues to be) an organ not only for the specialists at the Station, but also for the publication of articles on the most diverse aspects of biology in the Caribbean area, including systematic papers on reptiles, birds and insects. He will long be remembered for his persistence and energy in inducing reluctant contributors to prepare their manuscripts for publication, and then in correcting proofs at night with the aid of his wife, and struggling with an irascible printer to get their papers out on scheduled time.

At the time of his death he was residing in College Park. His last active assignment was as Visiting Professor, Louisiana State University. Previously he had been Professor of Plant Pathology at Delaware Agricultural Experiment Station 1907–11 followed by service in the same capacity at Rutgers University 1911–1923.

GEORGE WALCOTT

Lawson Caesar

1870-1952



Professor Lawson Caesar died suddenly at his home at Guelph, Ontario, on April 27th, 1952. He had been in good health and his sudden death was a great shock to his many friends.

Professor Caesar was born at Mono Road, Ontario, on February 15th, 1870. He was graduated from the University of Toronto in 1895. Following graduate work at the University of Oxford he taught classics in Ontario High Schools for several years.

Early in life Professor Caesar had developed a keen interest in nature and this finally led him to enter the Ontario Agricultural College in order to major in entomology.

Following his graduation in 1908 he joined the staff of the Department of Entomology and Zoology of the Ontario Agricultural College and here he continued in active service until his retirement in 1940. As Provincial Entomologist and Professor of Eco-

nomic Entomology Professor Caesar not only directed the regulatory work in entomology for the Province but was in charge of research and extension in the applied field and also administered the courses in economic entomology of his department. During his time of service all this was expanded greatly. Professor Caesar personally carried out an extended program in applied entomology. Much of this was pioneer work for his Province. It is especially worthy of note that he began the present spray service for fruit growers of the Province. He was the author of many bulletins and papers on the biology of insects and their control.

Results of Professor Caesar's work were always available to others. He had, accordingly many appreciative friends amongst the workers in entomology throughout Canada and the United States. Evidence of this appreciation lies in his election to the presidency of the Entomological Society of Ontario and the vice-presidency of the Entomological Society of America.

Many workers in entomology owe much to Professor Caesar not only for the contributions which he made but, also, for the inspiration and help which they received personally from him—either as students or co-workers.

As a man and a colleague Professor Caesar endeared himself to all with whom he came in contact. His kindly nature, his quiet sense of humor and his sincere desire to be of help to any and all made him much beloved. He was a professing Christian who practised his profession. There are many who would bear testimony to this.

Professor Caesar kept up his interest in entomology to the end and frequently visited his old department to discuss current problems in the insect world. He will be missed greatly.

A. W. BAKER

APPROVED ADDITIONS TO COMMON NAME LIST, AND ONE PROPOSED CHANGE

The Committee on Common Names has approved proposals for the following additions to the Common Name List. In accordance with current procedure for adding to the List, members are requested to indicate any disapproval of the present proposed additions within 30 days after receipt of the JOURNAL, preferably by writing to the undersigned. Unless substantial reasons for disapproval are given, the additions will stand as approved by the Association.

COLEOPTERA

Galerucella carbo (Lec.).... Pacific willow leaf beetle
Coccinella transversoguttata Fald.... transverse lady beetle
Miccotrogus picirostris (F.)..... clover seed weevil

LEPIDOPTERA

Malacosoma lutescens (N. & D.).... prairie tent caterpillar

HEMIPTERA

Psylla negundinis Mally..... boxelder psyllid
Colladonus montanus (Van D.).... mountain leafhopper
Corythucha arcuata (Say)..... oak lace bug
Perillus bioculatus (F.)..... two-spotted stink bug

HYMENOPTERA

Neodiprion americanus americanus (Leach).... loblolly pine sawfly
Neodiprion swainei Midd.. Swaine jack-pine sawfly
Neodiprion virginiana Roh.... red-headed jack-pine sawfly

ORTHOPTERA

Ectobius livens (Turton).... spotted Mediterranean roach
Leucophaea maderae (F.)..... Madeira roach

ARACHNIDA

Ixodes kingi Bishopp..... rotund tick

DIPTERA

Ophiomyia lantana (Frogg.)..... lantana seed fly
Cerodontha dorsalis (Loew)..... grass sheath miner
Liriomyza langei Frick..... pea leaf miner
Phytomyza ilicicola Loew.... American holly leaf miner

ISOPTERA

Reticulitermes flavipes (Kollar).... eastern subterranean termite

A Proposed Change to the list of approved Common Names

Thamnosphecia pyri (Harris) (Lepidoptera). It has been proposed that the name be changed from "pear borer" to "apple bark borer," for the reason that *pyri* is much more important on apple than on pear. The change has been approved by the Committee. An effort has been made to secure the opinions of representative entomologists familiar with northeastern fruit pests, and, thus far, no important objections have been raised. Members who disapprove should register their objections in the same way as for proposed additions.

ASHLEY B. GURNEY
Chairman, Committee on Common Names of Insects
U. S. Bureau of Entomology and Plant Quarantine
Washington 25, D. C.

NEW YORK STATE COLLEGE OF AGRICULTURE AT CORNELL UNIVERSITY

Dr. J. Chester Bradley who has achieved international recognition as an entomologist will retire from the department of entomology at Cornell University, July 1, 1952.

A lifelong collector, Dr. Bradley has travelled to many parts of the world and has added thousands of specimens to the Cornell collection. His interest in entomology was reported to have begun at the age of three when he brought spiders into an Agassiz Club meeting in West Chester, Pennsylvania, his native city.

In 1917 Dr. Bradley and several Cornell faculty members and students as well as other scientists made a transcontinental collecting trip in three cars and a trailer. "It wasn't done in those days," he said, and the group attracted considerable attention wherever they stopped. The specimens collected on the trip are still a part of the Cornell collection. Two years later he was director of the Cornell Entomological Expedition to South America and collected insects throughout almost the entire continent.

Dr. and Mrs. Bradley travelled in Europe and most of Africa in 1948–49, bringing back to the University more than 15,000 specimens. Last year they were in Europe again and late this fall they plan a trip to Mexico.

These trips have given him a wide acquaintance

with foreign entomologists and entomological societies in France, Germany, Belgium, Italy, London, Chile, and Argentina have honored him with membership.

With Dr. E. Laurence Palmer he wrote the manual of insect life for the Boy Scouts and has written several other manuals and laboratory guides. He has made more than 100 contributions to scientific periodicals and his articles have appeared in publications in most of the major countries of the world.

At present he is writing a book on the African Scoliidae.

One of the founders of the Entomological Society of America he is credited with giving the Society "the push it needed" in Philadelphia in 1905. He served as its first secretary-treasurer and was president last year.

Particularly interested in the International Congresses of Entomology, he has attended every meeting since the Ithaca Congress of 1928, going to Paris, Madrid, Berlin, Stockholm, and Amsterdam. He is one of two American members of the permanent organizing committee for these Congresses. He is also one of three American members of the International Commission on Zoological Nomenclature.

ABSTRACT OF REPORTS OF THE COMMITTEE ON PESTICIDES OF THE AMERICAN MEDICAL ASSOCIATION

PHARMACOLOGY AND TOXICOLOGY OF CERTAIN ORGANIC PHOSPHORUS INSECTICIDES. Journal of the American Medical Association 144: 104–8, Sept. 9, 1950.

GENERAL DESCRIPTION OF THEIR ACTIVITY AND USEFULNESS, by S. A. Rohwer and H. L. Haller. (p. 104)

Hexaethyl tetraphosphate (HETP) is essentially a mixture of esters containing ethyl metaphosphate, triethyl orthophosphate and 15 to 20 per cent tetraethyl pyrophosphate (TEPP), the principal insecticidal component.

Commercial hexaethyl tetraphosphate or tetraethyl pyrophosphate are straw colored liquids with a specific gravity of 1.28 to 1.29 at 25/25 C. Both are stable at room temperatures but decompose with the formation of ethylene gas at elevated temperatures. They are hygroscopic and miscible with water and many solvents but not with kerosene. In water they hydrolyze rapidly and they are of no insecticidal value and appear to be harmless to warm-blooded animals.

Parathion is a coined name for 0,0-diethyl 0-p-nitrophenylthiophosphate of purity above 95 per cent. Commercial parathion is a yellow deep brown liquid, some samples of which have a characteristic odor usually associted with onions. The boiling point of this compound is 375 C. or higher at 760 mm. pressure; its specific gravity is 1.26 to 1.28 at 25/25 C. It is very slightly soluble in water (about 20 p.p.m.), completely miscible with many organic solvents and practically insoluble in petroleum ether, kerosene and refined spray oils.

PHARMACOLOGY, by Kenneth DuBois, J.A.M.A. (p. 105)

The physiologic effects of the organic phosphorus insecticides are similar. The manifestations of acute poisoning resemble those produced by excessive nerve stimulation and the materials may be classified as cholinergic agents.

Signs of poisoning appear within five minutes after parenteral administration and death from a single dose of HETP or TEPP usually occurs within two hours. Respiration rate increases followed by unsteadiness, lack of coordination and muscular twitching. Myosis, defecation, urination, lacrimation and salivation occur. Prostration, general muscular fibrillations, convulsions and death follow. After a sublethal dose the cholinesterase activity returns promptly and symptoms disappear. Repeated doses lead to cumulative toxic action, each succeeding dose producing more severe symptoms and ultimate death. HETP and TEPP are rapidly detoxified through hydrolysis in the body, and storage in the tissues does not occur. Parathion is detoxified more slowly and subacute poisoning from repeated exposures is a possibility.

Since there is little difference in the susceptibility of different species of experimental animals to HETP, TEPP and parathion it may be expected that results with lower animals would be applicable to man. The LD_{50} of HETP for rats is about 2.5 mg. per kg. when given intraperitoneally, intravenously or by respiration and 7 mg. per kg. orally. The LD_{50} of TEPP is 0.65 mg. per kg. for rats and 0.85 for mice by the intraperitoneal route; given orally to rats it is 1.4 mg. per kg. The LD_{50} of parathion for male rats is 7 mg. per kg. when given intraperitoneally. Parathion given intraperitoneally to mice showed an LD_{50} of about 10 mg. per kg. These values for cats and dogs were 3 to 5 mg. per kg. and 12 to 20 mg. per kg. respectively when administered intravenously. Age or weight did not affect susceptibility within a species.

TOXICOLOGY, by David Grob, J.A.M.A. (pp. 105–7)

The organic phosphorus insecticides are among the most toxic materials used for pest control. Acutely TEPP is the most toxic. It is two to three times as toxic as HETP and several times more so than nicotine. Parathion is less toxic than HETP or TEPP. However, it is more stable in water and has a greater solubility in lipid media thus making it more dangerous from an over-all viewpoint.

These phosphorus compounds inhibit the cholinesterase enzymes. Initial inhibition is partly reversible in man. Repeated exposures before the restoration of the cholinesterase is dangerous. Cholinesterase of the tissues may be reduced considerably without the appearance of symptoms. TEPP and HETP even in great dilutions produce myosis. This effect on the eyes is especially important to pilots. The maximum dilutions of parathion recommended for spraying do not produce myosis.

The fatal dose of alkyl phosphates for man has not been determined. The single dose of TEPP that will produce marked symptoms is 5 mg. intramuscularly and 25 mg. orally. It is estimated that 25 mg. intramuscularly, 100 mg. orally, and 500 mg. cutaneously as a single dose would be lethal to man.

The first symptoms of phosphorus poisoning to appear are anorexia and nausea. These are soon followed by vomiting, abdominal cramps, excessive sweating, salivation and usually some degree of pupillary constriction. If the exposure is extensive, diarrhea, tenesmus, involuntary defecation and urination, pallor, pinpoint nonreactive pupils, blurred vision, excessive bronchial secretion, sometimes respiratory difficulty and pulmonary edema with cyanosis follow. Some people exhibit nicotine-

like effects including muscular fasciculations in the eyelids and tongue. These may be followed by fasciculations in the muscles of the faces and neck resulting in jerking movements of the eyes and then by generalized fasciculations and weakness. Central nervous symptoms when manifest include giddiness, uneasiness, restlessness, anxiety and tremulousness, followed by headache the sensation of "floating," insomnia and excessive dreaming. If the exposure is extensive, ataxis, tremor, drowsiness, difficulty in concentrating, mental confusion and occasionally disorientation develop. Paresthesias are common after exposure to TEPP, while changes in speech consisting of slurring, difficulty in forming words and multiple repetition of the last syllable may occur after parathion. In very severe cases this is followed by coma, with the disappearance of all reflexes, and then by generalized convulsions.

The acute symptoms last 6 to 30 hours. Others may persist 48 to 72 hours. The average time between last exposure and death from parathion has been 10.5 hours.

Parathion may be detected chemically in the organs. The cholinesterase activity of the brain, liver, and kidneys are depressed 22 to 88 per cent and that of the blood to below 20 per cent of normal.

Treatment is chiefly with atropine, which has a moderate inhibitory effect on the muscarine-like and a less striking effect on the central nervous system manifestations. Patients who have moderately severe symptoms due to these compounds have an increased tolerance for atropine. It is recommended that 2 mg. of atropine be administered intramuscularly at hourly intervals, or more often if necessary, until signs of atropinization appear. The dose of atropine may then be reduced, but its administration should be continued as long as any muscarine-like symptoms are present. Atropine should not be administered prophylactically unless the patient can be observed for 24 hours, as it may delay the symptoms of poisoning. Adjuvants to atropine therapy include washing the skin, ocular irrigation and gastric lavage to remove any unabsorbed insecticide, parenteral replacement of fluids, administration of oxygen and tracheal intubation and artificial respiration if necessary.

To reduce absorption through the skin, clean protective clothing is required. Workmen engaged in the manufacture of the chemical, formulation or blending of insecticides should wear complete protective equipment including natural rubber gloves, goggles, rubber overshoes and aprons. Workmen engaged in applying insecticides need not use rubber aprons and rubber overshoes, if care is exercised. All clothing worn by workmen should be washed before reuse.

To reduce absorption through the respiratory tract, workmen engaged in manufacture or packaging of the chemical or insecticides should be protected by adequate exhaust ventilation. Personnel engaged in application of aerosols in greenhouses and pilots applying insecticides by aircraft should wear full face masks, tested to provide protection from organic vapors, mists and dusts. Personnel engaged in applying insecticides out-of-doors should avoid repeated or excessive exposure to dust, mist or vapor. Those applying insecticides containing parathion should wear respirators equipped with cartridges and filters of the type advised by the United States Department of Agriculture. Wind dispersal of insecticides to unprotected personnel or domestic animals should be avoided.

To reduce absorption through the gastrointestinal tract, personnel should remove protective clothing and wash hands, arms and face thoroughly with soap and water before eating, drinking or smoking. Parathion may persist for varying periods as residues on plants. Such residue may present some hazard to those who handle or use agricultural products or work in treated areas.

Empty containers of phosphorus insecticides should be burned. Metal and similar containers should be washed (with alkali if practical), and perforated to prevent reuse.

To prevent cumulative effects in personnel who are frequently exposed to organic phosphorus insecticides the periodic determination of the cholinesterase of plasma and red-blooded cells is advised. Persons with reduced cholinesterase activity should be removed from all exposure until this enzyme has returned to normal. A number of other precautions are included by the author.

CLINICAL EXPERIENCE, by Herbert K. Abrams, Donald O. Hamblin, and John F. Marchand, J.A.M.A. (pp. 107–8)

In the production and use of phosphorus insecticides 198 cases of poisoning have been reported. Of these 6 were from HETP (0 fatalities), 24 from TEPP (1 fatality—child), and 168 from parathion (7 fatalities). Among agricultural workers there were 135 cases against 59 in industry. Brief description is given of the eight authenticated fatalities.

EFFECTS ON BENEFICIAL FORMS OF LIFE, CROPS AND SOIL AND RESIDUE HAZARDS, by A. J. Lehman, Albert Hartzell, and J. C. Ward, J.A.M.A. (p. 108)

The extreme toxicity of the phosphorus insecticides indicates they can harm beneficial forms of life. Their use on livestock and pets is not recommended. Except for direct application to animals little hazard exists with HETP and TEPP because of lack of residual properties. Parathion leaves residues, therefore it should not be used on plants in bloom, or in excessive quantities around fish and wildlife habitats.

With the exception of certain varieties of chrysanthemums, plants tolerate recommended concentrations of HETP and TEPP. Parathion injures a number of fruits (certain varieties of apples and pears) and vegetables (young cucumbers, squash and tomatoes) and dormant plants. HETP, TEPP and parathion do not accumulate in the soil. Parathion on turf may present a health hazard.

Life-time feeding of parathion to rats gave no indication of cumulative effects when levels were below 25 p.p.m. Levels from above 25 p.p.m. to 100 p.p.m. produced nervous symptoms and inhibited blood cholinesterase. A safe residue level on any one item of diet would be approximately 2 p.p.m.

Recommendations of the Bureau of Entomology and Plant Quarantine for use of parathion on apples and pears are considered safe but the lowest concentration effective against insects and mites on citrus may leave 2 or 3 p.p.m. in the peels and there is question of the safety of using such peel for food. If spray schedules recommended by qualified entomologists are followed, it is quite unlikely that a parathion spray residue problem will become serious.

Abstracts of other reports on pesticides will follow.

F. C. BISHOPP

A Committee on Pesticides has been set up by the American Medical Association under the Council of Pharmacy and Chemistry. This Committee now consists of Torald Sollmann, Herbert K. Abrams, Kenneth P. Dubois, Herbert L. Haller, Albert

Hartzell, Culver S. Ladd, Arnold J. Lehman, S. W. Simmons, Justus C. Ward, and Bernard E. Conley (Secretary).

The committee has issued three reports dealing with aspects of pesticides which are of immediate medical interest. These have been published in the Journal of the American Medical Association and a limited number of reprints are available.

The Subcommittee on Entomology of the National Research Council concluded that the information in these reports should be abstracted for the benefit of entomologists and arrangements were made for the JOURNAL OF ECONOMIC ENTOMOLOGY to publish abstracts of the reports already available and others as they are presented in the Journal of the American Medical Association.

INTERDEPARTMENTAL COMMITTEE ON PEST CONTROL

Depts. of Agriculture—Interior—Army—Navy—Airforce and Federal Security Agency

June 4, 1952

ENDRIN—A coined name for the insecticidal chemical 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,4,5,8-endo-endo-dimethanonaphthalene.

The word "endrin" has been selected as a coined name for the insecticidal chemical, 1,2,3,4,10,10-hexachloro-6,7-epoxy-1,4,4a,5,6,7,8,8a-octahydro-1,-4,5,8-endo-endo-dimethanonaphthalene. This formula is identical to DIELDRIN, except that DIELDRIN is the endo-exo isomer. Endrin has been approved by the Interdepartmental Committee on Pest Control, and the name is agreeable to the American Chemical Society. Endrin has been known as Experimental Insecticide No. 269.

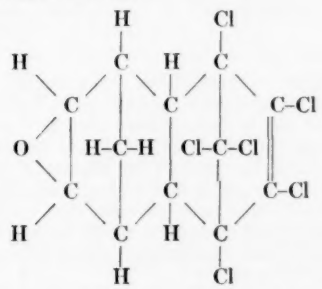
A research report, based upon United States Patent Office records, marks registered in the forty-eight states, Common Law Marks published in Trade Association Lists, Business Titles, Trade Names and Corporate Titles has resulted in the assurance that the name, endrin, may be legally adopted as the common name for an insecticidal chemical without interference with presently registered trade-marks or trade names. The name "endrin" therefore is available for use as a common name for designating this chemical.

The name "endrin" applies to the pure chemical; the technical grade material shall indicate the percentage of endrin present.

Physical and Chemical Properties

Empirical Formula: $C_{12}H_8Cl_6O$

Structural Formula:



Endrin is a white, crystalline solid which melts with gradual chemical rearrangement when heated above 200° C. The chlorine atoms of endrin are not removable with the usual alkaline reagents refluxing of the compound with metallic sodium in isopropanol is required to effect dehalogenation. Acids cause endrin to rearrange into an insecticidally inactive derivative.

Solubility

Endrin is insoluble in water but is soluble in the usual organic solvents. The solubility of endrin in aromatic hydrocarbon solvents such as benzene and xylene is greater than in paraffinic solvents such as hexane or kerosene.

Compatibility

Endrin is stable to alkalis and is unaffected by acidic conditions normally encountered in agriculture. This material is compatible with the commonly used insecticides, fungicides and herbicides.

Phytotoxicity

Endrin seems to be tolerated by most plants when used at concentrations necessary for insect control. Corn buds have shown signs of "burn" when the corn plant was sprayed for corn earworm control. Ears of corn whose silks have been treated for corn earworm control were not contaminated with odor or flavor. Cucumbers have also shown a slight burning of foliage after treatment.

Insecticidal Properties

Field tests with endrin in 1951 indicate that endrin would be useful for certain pests of agricultural crops. These include certain cotton insects such as the boll weevil, the bollworm, the tobacco budworm, the variegated cutworm, the fall armyworm, and the tarnished plant bug. In addition, endrin has looked promising for the control of tobacco hornworms, sugar beet webworm, corn earworm, Mexican bean beetle, European corn borer, as well as various aphids attacking nursery stock. An experimental program for 1952 will place special emphasis on evaluating endrin against various Lepidoptera Hemiptera and Homoptera.

Mammalian Toxicity

Tests for its acute oral toxicity to laboratory white rats showed the median lethal dose (LD-50) of endrin to be 10-12 milligrams per kilogram of body weight. Subacute and chronic toxicological investigations of this compound are under way. Based on existing information, it is evident that the compound, particularly in the more concentrated form, will have to be handled with caution. However, because of its high order of insecticidal effectiveness, coupled with its moderate residual characteristics, the mammalian toxicity of endrin is not expected to preclude the use of effective quantities of this product except on food and forage crops nearing harvest.

Analytical Methods

Three methods of analyses for endrin are now being employed: (1) bio-assay, using *Musca domestica*, (2) infra-red spectroscopy and (3) total chlorine.

Available Formulations

The following formulations of endrin are available for large scale evaluation:

19% emulsifiable concentrate
(1.6 pounds actual per gallon)
25% wettable powder
2% dust

Precautions

Insecticidal formulations containing endrin should be handled with extreme care, both by the formulator and by the ultimate user. It is most important that contaminated clothing be removed and laundered and the product be washed off the skin promptly. Formulating and mixing plants should be equipped with ventilation facilities that will prevent inhalation of endrin dusts or mists. During application of endrin insecticides, the wearing of respirators should be enforced.

June 4, 1952

ISODRIN—A coined name for the insecticidal chemical 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-endo-endo-dimethanonaphthalene.

The word "isodrin" has been selected as a coined name for the insecticidal chemical, 1,2,3,4,10,10-hexachloro-1,4,4a,5,8,8a-hexahydro-1,4,5,8-endo-dimethanonaphthalene. This formula is identical to ALDRIN, except that ALDRIN is the endo-exo isomer. Isodrin has been approved by the Interdepartmental Committee on Pest Control, and the name is agreeable to the American Chemical Society. Isodrin has been known as Experimental Insecticide No. 711.

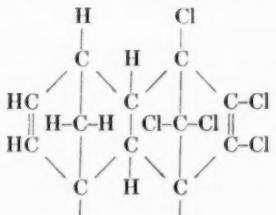
A research report, based upon United States Patent Office records, marks registered in the forty-eight states, Common Law Marks published in Trade Association Lists, Business Titles, Trade Names and Corporate Titles has resulted in the assurance that the name, isodrin, may be legally adopted as the common name for an insecticidal chemical without interference with presently registered trade-marks or trade names. The name "isodrin" therefore is available for use as a common name for designating this chemical.

The name "isodrin" applies to the pure chemical; the technical grade material shall indicate the percentage of isodrin present.

Physical and Chemical Properties

Empirical Formula: $C_{12}H_8Cl_6$

Structural Formula:



Isodrin is a white, crystalline solid which is slowly decomposed when heated above 100° C. The chlorine atoms of isodrin are not removable with the usual alkaline reagents refluxing of the compound with metallic sodium in isopropanol is required to effect dehalogenation. In single phase solutions, strong mineral acids will add to the double bond of isodrin.

Solubility

Isodrin is insoluble in water but is soluble in the usual organic solvents. The solubility of isodrin in aromatic hydrocarbon solvents such as benzene and xylene is greater than in paraffinic solvents such as hexane or kerosene.

Compatibility

Isodrin is stable to alkalis and is unaffected by acidic conditions normally encountered in agriculture. This material is compatible with the commonly used insecticides, fungicides and herbicides.

Phytotoxicity

Isodrin seems to be tolerated by most plants when used at concentrations necessary for insect control. Corn buds have shown signs of "burn" when the corn plant was sprayed for corn earworm control.

Insecticidal Properties

Field tests with isodrin in 1951 indicate that isodrin will be useful for the control of certain pests on agricultural crops. Isodrin shows promise for the control of the European corn borer, corn earworm, sugar beet webworm, tobacco hornworms, thrips, leafhoppers and various aphids. During the experimental program for 1952 special emphasis will be placed on evaluating isodrin for the control of various Lepidoptera, Hemiptera and Homoptera.

Mammalian Toxicity

Tests for its acute oral toxicity to laboratory white rats showed the median lethal dose (LD-50) of isodrin to be 12–17 milligrams per kilogram of body weight. Subacute and chronic toxicological investigations of this compound are under way. Based on existing information, it is evident that the compound, particularly in the more concentrated form, will have to be handled with caution. However, because of its high order of insecticidal effectiveness, coupled with its moderate residual characteristics, the mammalian toxicity of isodrin is not expected to preclude the use of effective quantities of this product except on food and forage crops nearing harvest.

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H. L. HALLER, *Chairman*
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PROCEEDINGS OF THE THIRTY-SIXTH ANNUAL MEETING PACIFIC BRANCH AMERICAN ASSOCIATION OF ECONOMIC ENTOMOLOGISTS

Santa Barbara, California, June 24, 25, and 26, 1952

The thirty-sixth annual meeting of the Pacific Branch was held in Santa Barbara, California, June 24, 25, and 26, 1952. The officers during the meeting were: Glenn E. Carman, *Chairman;* Stanley F. Bailey, *Vice-Chairman;* and Leslie M. Smith, *Secretary-Treasurer.* The chairmen of the various committees were: L. D. Anderson, *program;* C. H. York, *arrangements;* Mrs. R. E. Campbell, *arrangements for ladies;* O. P. Steinen, *registration;* M. E. Cravens, *operations;* H. M. Armitage, *press;* W. M. Hoskins, *residues;* M. M. Barnes, *membership;* C. P. Clausen, *resolutions;* R. E. Campbell, *auditing;* H. S. Telford, *employment service;* J. N. Roney, *nominations.* Acting chairmen at various times during the meeting were Glenn E. Carman, E. P. Breakey, J. N. Roney, A. W. Lindquist, L. D. Anderson, R. B. March, and S. F. Bailey.

The meeting was opened by an address by Dr. E. F. Knipling, President of the American Association of Economic Entomologists. Dr. Knipling stated that because of the crowded programs of the national meetings the branch meetings are necessarily assuming greater importance.

Dr. A. M. Boyce presented a very interesting illustrated discussion of entomological problems of Asia, the Middle East, and Africa. Another invitational speaker, Dr. E. J. Hambleton, gave a thorough discussion of entomology in the point IV program. There were 52 submitted papers, 5 panel discussions, and 5 movies. Because of the crowded program, the movies were repeatedly shown, concurrently with the paper reading sessions.

The panel discussions were as follows: *Recent development in biological control,* C. H. Fleschner, moderator, P. H. DeBach, K. S. Kagen, C. B. Huffaker, I. M. Newell, R. van den Bosch, and C. G. Thompson. *Pesticides and pollinators,* R. F. Smith, moderator, L. D. Anderson, B. Harlan, J. E. Eckert, W. Miller, R. R. Reed, F. E. Todd, F. V. Lieberman, J. W. MacSwain, and A. B. Lemmon. *The objectives of entomological training,* W. Ebeling, moderator, E. W. Bodine, L. A. Carruth, E. T. Doyle, P. L. Rice, R. F. Smith, R. A. Fisher, and M. Sherman. *Recent developments in virus vector research,* L. S. Jones, moderator, H. M. Armitage, E. W. Anthon, R. C. Dickson, H. R. McCarthy, J. H. Freitag, D. D. Jensen, E. S. Sylvester, and N. S. Wilson. *Systemic insecticides,* R. L. Metcalf, moderator, E. W. Anthon, R. L. Jeppson, W. H. Lange, Jr., J. M. Magner, R. B. March, A. L. Abel, and R. N. Jefferson.

During the business meetings, Chairman Glenn Carman appointed the auditing committee, consisting of R. E. Campbell, chairman, R. L. Metcalf, and R. E. Miller. J. C. Chamberlin completed his term of office as a member of the Executive Committee, and J. F. Kagy was nominated to fill this vacancy, and duly elected.

A motion was passed instructing the three members of the program committee (to be appointed by the incoming chairman) to make a thorough study of the basic plan for the program for the next meeting. This study should include factors such as the amalgamation of the two societies, the greatly increased membership of the Pacific Branch which will probably total about 1,100 by the time of the next meeting, the great increase in the number of submitted papers, and the necessity for holding concurrent, sectional meetings.

A motion was passed which instructed the incoming chairman to appoint a committee to work cooperatively with the national committee on place of holding the national meetings. The purpose of this committee is to focus attention on the equitable, geographic distribution of national meetings.

The following reports were accepted by the members:

TREASURER'S REPORT

	Credits	*Debits*
Balance in Treasury, June 18, 1951	$368.43	
Registration fees, 1951 meeting and miscellaneous income	223.70	
Mimeographing, Resolution 7		$ 9.70
Typing minutes, 1951 meeting		8.00
Purchase of photographs		15.00
Addressing and mailing Resolution 7		6.00
Printing letterhead stationery		28.33
Stamped envelopes		36.68
Printing announcement of meeting		33.04
Addressing and mailing announcements		26.00
Stamped envelopes		36.32
Mimeographing hotel list		1.10
Deposit on Secretary's room, check 29		10.00
Printing program		164.60
Addressing and mailing programs		30.00
	592.13	404.77
Balance in Treasury, June 23, 1952		187.36
	$592.13	$592.13

LESLIE M. SMITH, *Secretary-Treasurer*

REPORT OF THE AUDITING COMMITTEE

We have examined the accounts of the Treasurer and find them to be correct.

ROY E. CAMPBELL, *Chairman*
ROY MILLER
R. L. METCALF

REPORT OF THE MEMBERSHIP COMMITTEE

Eighty-three new members have joined the Pacific Branch during the past year.

M. M. BARNES, *Chairman*
H. S. TELFORD
A. E. PRITCHARD
C. C. CASSILL

REPORT OF THE COMMITTEE ON EMPLOYMENT

It is the opinion of the majority of the Committee on Employment Service, after due consideration of all proposals, that no practical approach to this question appears evident.

WM. J. F. FRANCIS, *Acting Chairman*
M. C. SWINGLE
H. S. TELFORD
L. M. SMITH

REPORT OF THE COMMITTEE ON TOXICITY AND RESIDUES

A Standing Committee was authorized two years ago to consider and report at the annual meetings on the problems arising from residual insecticides and

especially to consider how the Pacific Branch may assist in overcoming the relative lack of facilities for residue and toxicity study in the west. At the Seattle meeting a resolution was offered and adopted urging the Delaney Committee not to disturb the present licensing system. An enlarged committee this year has attempted to come to grips with the matter which is not solving itself but indeed is more serious all the time.

Some pertinent developments are:

a) New insecticides, fungicides and weed killers are coming into use despite increasing restrictions. This is in part due to:
b) development of resistance to an increasing list of chemicals.
c) hold over effects of some chemicals upon flavor and customer acceptance of foods. This may follow either application to plants, to soil or to the environment as in treatment of chicken houses for fly control. Systemic insecticides threaten to increase the problem.
d) slowness of regulating authorities in taking action such as fixing of tolerances by the FDA is an unsettling factor.
e) alarming statements are appearing in the papers and magazines about poisons in food. A single instance, even one falsely interpreted, given wide publicity could set off a torrent of public alarm.

This list might be lengthened considerably, but in reality the troubles stemming from agricultural chemicals getting into foods all come from lack of sufficient reliable information on two subjects:

1) How toxic is each chemical *as it reaches the consuming public*? and
2) How much chemical does reach the consuming public as a result of pest control practices?

Entomologists cannot take part directly in solving the toxicity problems, but they have a right to insist that the toxicologists carry out their feeding tests, etc., under realistic conditions. Thus the production of some pathological condition in an animal given say 100 times as much chemical X as could possibly be eaten in natural food is merely a laboratory observation and does not justify planting the suspicion that if a lot causes obvious harm, a little probably does the same in a more insidious manner.

On the subject of how much contamination does result from insect control practices, the entomologist is the key figure. Chemists usually do the analyses but their samples should be truly representative of what is done in practical pest control. This is quite different from the inherent reliability of the analytical data which is governed by such matters as number of samples, consistency of repeated tests, background contamination or interference and recovery of known amounts of insecticide. These are matters which can be standardized, though but little progress has been made. One step is the suggestion by the FDA that 10 samples should be taken from different regions in order to establish the range of residue for a particular use of a given chemical. There is great need for consultation among analytical laboratory workers on all these matters.

Establishment of a range of residue for various insecticides on a country-wide basis is of limited usefulness to an entomologist who must make recommendations for a certain area. Conditions differ so greatly that it is possible to establish a relation between application of chemical and resulting residue only on a regional basis. Hence deposit and residue data must be collected for each part of the country. Here is where the Pacific Branch may exert a useful influence. The west is woefully weak in facilities for either toxicity or residue determination despite our immense agriculture. As individuals, entomologists may urge State agricultural directors, agricultural experiment station directors, and industry managers to initiate or expand such work, but the official voice of western entomologists will have a much greater influence.

Your committee has not drawn up any resolutions but it wishes to suggest that if the membership present decide to authorize a committee to continue this activity the following matters may be worth considering:

1) Consult with the national AAEE officers and especially with the committee on toxicology, headed by Dr. Palm of Cornell, on how organized entomologists may take a more active part in solving the problems which arise from their pest control practices. Possibly the Pacific Branch may take the lead in such a program, especially in presenting our case to the public through farm journals and other outlets.

2) consult with the Pesticide Section of the Division of Agricultural and Food Chemistry of the American Chemical Society and with local sections of the ACS in standardizing sampling and analytical procedures for residue determination, by either chemical or biological methods.

3) compile from all available sources a list of laboratories in the west where residue determinations are being done or may be initiated, and the number and qualifications of the personnel in each.

4) consult with state, university, and industry authorities regarding the development of an information center for gathering, compiling, and distributing data on all aspects of the use of insecticides as they affect the quality of foods in the western states.

W. M. HOSKINS, *Chairman*
C. C. CASSILL
D. W. DEAN
F. A. GUNTHER
A. B. LEMMON
L. CHILDS

A motion was passed which instructs the incoming chairman to reappoint the above committee on residues, with instructions to proceed along the lines outlined in this report.

REPORT OF THE COMMITTEE ON RESOLUTIONS

Resolution No. 1.

WHEREAS, the members of the Pacific Branch of the American Association of Economic Entomologists, in attendance at the thirty-sixth annual meeting of this branch held in Santa Barbara, California on June 24, 25, and 26, 1952, have enjoyed a worthwhile and successful meeting and are deeply grateful to various agencies and organizations which have made this possible; therefore, be it resolved that thanks be extended to the various committees having to do with the organization and conduct of this meeting and especially

To Lauren D. Anderson, Chairman, and the other members of the Program Committee for their successful efforts in arranging the very interesting and valuable program.

To C. H. York, Chairman, and the other members of the Committee on Arrangements for their careful and thorough planning.

To the industrial and commercial concerns for

their generous financial aid in providing refreshments and a splendid repast at the barbecue held at American Legion Hall in Santa Barbara and transportation for all events.

To Committee on Arrangements for Ladies consisting of Mesdames R. E. Campbell, E. H. Littooy, H. B. Sheldon, and C. H. York.

To Glenn E. Carman, Chairman, Stanley F. Bailey, Vice-Chairman, and Leslie M. Smith, Secretary-Treasurer, for their untiring efforts in making possible this highly successful meeting.

To H. M. Armitage for splendid handling of press notices of our meeting; to Ed Littooy for his usual energetic liaison in successfully keeping events and committees running smoothly, and to all other committee members who have so generously given their time.

To Fred J. Trevillian of the Mar Monte Hotel where the organization met, to Tom Kleveland of the Santa Barbara News Press for competent news coverage, and to James Hamilton, Manager of the local Convention Bureau, for their splendid cooperation in handling our members and guests.

The committee suggests the secretary write a letter of appreciation and thanks to Messrs. Trevillian, Hamilton, and Kleveland.

REPORT OF THE NOMINATING COMMITTEE

For Chairman, S. F. BAILEY
For Vice-Chairman, A. W. LINDQUIST
Secretary-Treasurer, LESLIE M. SMITH's term of office expires 1954.

Respectfully submitted,
J. N. RONEY, *Chairman*
A. J. FLEBUT
E. G. LINSLEY

These officers were unanimously elected. This concluded the business meeting.

At a meeting of the Executive Committee it was decided to raise the registration fee for the June 1953 meeting to $1.50 per person. The secretary reported that there are 835 names on the Pacific Branch mailing list, and this has increased the costs of printing and mailing.

The meetings were made enjoyable by excellent weather and fine facilities provided by the hotel. The members enjoyed a barbecue dinner, floor show, and dance. A garden tour and luncheon were arranged for the ladies. A total of 339 members and guests registered and wives and families brought the total to 479.

MEMBERS AND GUESTS REGISTERED

Aarons, Theodore
Abel, A. L.
Ahmad, Rashid
Ahsan, Taoi
Allen, Frank D.
Allen, William W.
Andison, Harry
Ash, Alvin G.
Ames, Charles T.
Anderson, Lauren D.
Anthon, E. W.
Armitage, H. M.
Atkins, Larry

Badgley, Max E.
Bailey, S. F.
Baker, W. A.
Bannon, Ray R.
Barnes, Martin M.
Barrett, C. J.
Barron, F. Ray
Bashor, E. F.
Bemis, L. Roy
Benedict, S. H.
Benedict, W. V.
Berg, Elwood C.
Black, Gordon G.
Bodine, E. W.
Bohart, George E.
Boissonou, C. J.
Bonnell, Dan
Bottger, G. T.
Borden, A. D.
Bowen, Charles H.
Bowen, M. F.
Boyce, A. M.
Breakey, Ed
Bronson, Art
Brown, Frank A.
Browne, Ashley C.
Brunn, L. K.
Bull, Ted
Burden, Ivor R.
Burnside, W. H.
Burton, Vernon E.
Bussart, J. Everett

Caffrey, D. J.
Caldwell, Ralph W., Jr.
Campbell, Roy E.
Cannon, Earl W.
Carman, G. E.
Carruth, L. A.
Carter, G. J.
Carter, Robert Duncan
Carter, Walter
Choate, M. W.
Clark, Edgar William
Clark, John R.
Clausen, C. P.
Cook, F. E.
Cory, Ernest N.
Coulston, John C.
Cravens, Marcus
Cressman, A. W.
Cummings, Walter S.

Daehnert, R. H.
Darley, Merrill M.
Davis, Donald W.
Davis, James E.
Dean, D. W.
DeBach, Paul
Denning, D. G.
Dent, George
Diaz, Joe
Dick, Chas. V.
Dickson, R. C.
Dorman, Stephen
Doyle, E. T.
Dresher, Paul F.
Duggan, Charles E.
Duncan, Bruce
Durham, Wallace

Eads, Clark O.
Ebeling, Walter
Einmo, John R.
Elmer, Harold S.
Elmore, John C.
Erb, Larry W.
Erwin, Wallace
Esberg, A. M.
Ewart, W. H.

Farrar, W. W.
Ferguson, George R.
Ferris, C. A.
Fetzner, Chas. L.
Fisher, John R.
Fisher, Robert A.
Flebut, A. J.
Fleschner, C. A.
Fletcher, Fred W.
Flitters, Norman E.
Flock, R. A.
Fosen, E. H.
Francis, Wm. J. F.
Freitag, J. H.
Frost, Marvin H., Jr.
Fullmer, Oliver H.

Gammon, Cyril
Gardner, William B.
Garman, Ward W.
Garmus, Ralph P.
Geary, Robert J.
Gentner, Louis G.
Gerhardt, Paul D.
Gillies, Ken
Gjullin, C. M.
Gorham, Sam C.
Gunther, F. A.
Graves, C. E.

Hagen, Kenneth S.
Hall, Irvin M., Jr.
Hall, Phil
Hambleton, Edson J.
Hambleton, Jas. I.
Hamman, Robert E.
Hammer, O. H.
Hamsher, C. A.
Hanna, Lester W.
Hanson, Charles A.
Harden, Philip H.
Hardman, Newt
Hargett, E. G.
Harlan, J. Bernell
Harshberger, Don
Hassler, Karl
Hayward, Chas. J.
Heffernan, Tom
Heltman, Bruce
Heltman, Harold
Hillebert, Roy
Hiltabrand, Wray F.
Hitchcock, O. B.
Hodson, A. C.
Holmes, H. F.
Horn, W. E.
Hoskins, W. M.
Howard, Fred K.
Howland, Adelbert F.
Huffaker, Carl B.
Hughs, Ralph
Hunt, Chas. R.
Husbands, Richard C.
Hutchings, Floyd W.

James, Maurice T.
Jefferson, R. N.
Jensen, D. D.
Jeppson, Lee R.

Jesser, Milton J.
Johnson, E.
Johnson, Floyd A.
Johnson, Harold
Jones, Laurence
Jones, M. P.
Jonson, Wm. L.
Jordan, W. B.

Kagy, J. F.
Kaloostian, Geo. H.
Katzman, Morris
Keh, Benjamin
Kessler, Kenneth
Ketron, Wayne
Klein, Jack
Kido, H.
Kipple, Charles A.
Kirkpatrick, A. F.
Knipling, E. F.
Kolbegen, Martin J.
Korsmeier, R. B.
Krister, C. J.

LaFollette, J. R.
Lamoree, R. S.
Lange, W. Harry
Lawrence, T. C.
Leigh, Thomas
Lembright, Harold W.
Lemmon, Allen B.
Lewallen, Lawrence L.
Lewis, H. C.
Lewton, Ted
Lieberman, Frank V.
Lindgren, David L.
Lindquist, A. W.
Linsley, E. G.
Littooy; Ed.
Loeffler, Erwin S.
Lohr, A. D.
Lomax, Jack W.
Lorbeer, Howard B.
Lunsford, C. F.

Martin, David
MacCarthy, H. R.
MacLeod, G. F.
McDiarmid. F. H.
McEachery, E. H.
McIntyre, Wallace
McLane, F. B.
McLeod, J. H.
McNelly, L. B.
Mack, Bud
Magner, J. M.
Magy, Harvey I.
March, Ralph B.
Maxwell, K. E.
Messenger, Ken
Metcalf, Robert L.
Meyer, George A.
Meyer, Robert J.
Meyers, Ernest G.
Michelbacher, A. E.
Miller, Cecil E.
Miller, Roy E.
Moore, Arthur D.
Morrison, H. E.
Montenson, Earl W.
Mote, Don C.
Munger, Francis
Murphy, Vel E.
Myers, L. Emery

Nail, Jack
Neal, J. H.
Newell, Irwin M.
Newall, Warren R.
Nickel, John L.
Norland, Calvert E.
Norlin, E. L.

Olocco, Frank
Ortega, John C.
Osborn, H. T.
Osborne, Jim
Otis, Chet

Padget, L. J.
Pappas. Joe
Papke, Cliff
Penny, Don
Peters, Richard F.
Pfadt, Robert E.
Piquet, W. L.
Plowden, John G.
Poppic, George T.
Prendergast, David T.
Primm, J. K.
Pritchard, A. Earl

Reed, W. D.
Reeks, Lloyd D., Jr.
Reinhardt, J. F.
Reynolds, Harold T.
Rice, Paul L.
Rieder, Robert E.
Riehl, Louis A.
Roberts, Harry H.
Roney, J. N.
Roullard, Fred P.
Ryckman, Raymond E.

Schwab, Otto
Scott, Dave
Scudder, Harvey I.
Scullen, Herman A.
Sessions, A. C.
Shankland, D. L.
Sheldon, Howard B.
Shell, Lee
Sherman, Martin
Sherman, R. F.
Siverly, R. E.
Smith, Everett L.
Smith, Jack R.
Smith, Leslie G.
Smith, Leslie M.
Smith, Owen J.
Smith, R. C.
Smith, R. Clark, Jr.
Smith, Ray F.
Soroker, Robert H.
Stafford, E. M.
Starker, Chuck
Steinen, Otto
Steinweden, John B.
Stern, Vernon M.
Stewart, Deane
Stone, M. W.
Strew, Stanley W.
Stull, Carl R.
Swain, A. F.
Swift, Ed
Swingle, M. C.
Swoboda, Mike
Sylvester, E. S.

Taylor, Lyall F.
Teague, C. P.
Thomas, Hobart O., Jr.
Thompson, Clarence G.
Thomson, B. G.
Thomsen, Walter
Thorne, Fred
Todd, Frank E.
Toll, Carroll C.
Trombley, C. Nick
Tubbs, D. W.
Tuft, Ted
Turner, H. J.
Tuttle, Don

Underhill, R. W.
Upholt, William M.

van den Bosch, Robert

Walker, John R.
Wampler, Elvin L.
Warner, Robert M.
Watwood, Robert P.
Wegenek, Edward G.
Weldon, Geo. H.
West, James
Westgate, W. A.
White, R. O.
Williams, John N.
Wilson, Bernarr L.
Wilson, Norton S.
Winner, Christian
Woglum, R. S.
Woodbury, E. N.
Wood, Les, Jr.
Woolley, Vernon L.
Worthy, Walter L.

York, Converse

INDICES TO ECONOMIC ENTOMOLOGY

Index X to the Literature of American Economic Entomology for the year 1950 is now available. Pirice—$2.00.

Index IX for the years 1948–1949 will be ready to go to press about November 1952. This was delayed due to clerical difficulties and later resumed.

Index XI 1951 was closed on December 31, 1951 and is now in process of revision and retyping.

Members may secure the new indices at 25% reduction.

Non-members and libraries will be charged the list price. Book dealers allowed a 10% discount.

The following back indices are available.

Index I	$5.00
Index II	4.00
Index III	4.00
Index IV	4.00
Index V	4.50
Index VI	6.00
Index VII	7.00
Index VIII	7.00

Complete sets of the above may be obtained for $32.00 plus $.50 per volume for foreign postage.

List of Common names of Insects—approved by the American Association of Economic Entomologists—$.50 per copy. Make checks payable to the Association.

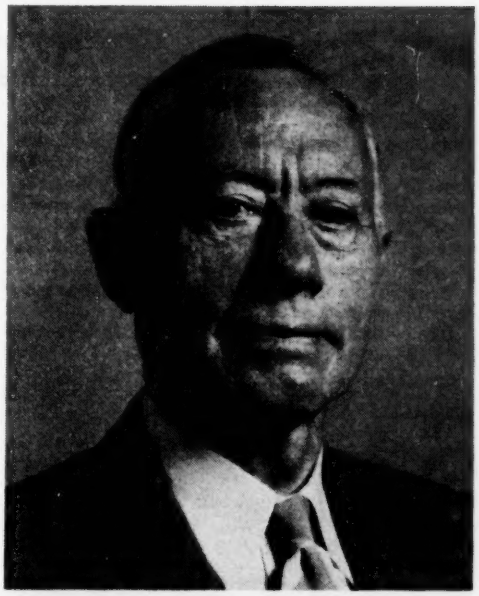
Ninth Edition of Entoma is still available. Price is $2.00. Order from and make checks payable to George S. Langford, Editor, College Park, Maryland.

USDA Entomologist Honored

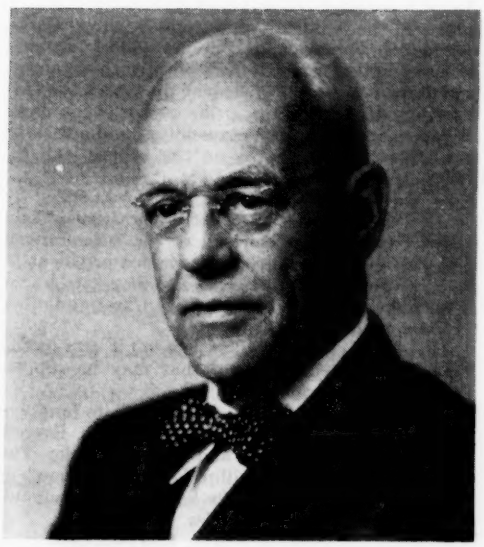
Dr. Fred C. Bishopp, assistant chief of the Bureau of Entomology and Plant Quarantine, U. S. Department of Agriculture, was honored for outstanding achievement by his alma mater, Colorado A. & M. College on June 6. Dr. Bishopp is the second of the institution's graduating entomologists to be so honored in the nine years that the college has been making such presentations in connection with commencement ceremonies. The other entomologist cited for his achievement was the late Dr. P. A. Annand who was chief of the Bureau of Entomology and Plant Quarantine from 1941 to 1950.

Dr. Bishopp has been with the U. S. Department of Agriculture since 1904. He has progressed from the position of special field agent to his present responsible post. During World War II, Dr. Bishopp served as adviser to the Surgeon General of the Army in Australia and New Guinea, working to introduce new methods of malaria control and scrub typhus prevention. For several years he has served on the advisory committees of the U. S. Public Health Service, the Army and Navy. For the part he played in the direction of research leading to the development and use of DDT and other insect control agents for the protection of Allied Armies for malaria, typhus, desentery, dengue and other diseases he was awarded "His Majesty's Medal for Service in the Cause of Freedom" by the British Government.

Dr. Bishopp received his bachelor's degree from Colorado A. & M. in 1902 and his master's degree in 1926. He received his Ph.D. from Ohio State University in 1932.



Dr. Fred C. Bishopp



Dr. J. R. Parker

J. R. Parker Honored

Dr. J. R. Parker of the Division of Cereal & Forage Insect Investigations, Bureau of Entomology and Plant Quarantine, who has been in charge of the grasshopper research program with headquarters at Bozeman, Montana, for the past twenty years, is now giving full time to the preparation of important manuscripts on grasshoppers. Mr. Frank T. Cowan, long associated with the grasshopper and Mormon cricket investigations, succeeded Dr. Parker on July 1, 1952.

Dr. Parker with his fine background of experience in grasshopper research is well fitted for studying, analyzing, and summarizing the large amount of valuable field data which have been assembled under his direction. In addition, he will continue as consultant and advisor in connection with current grasshopper research programs.

The Department of Agriculture conferred its Distinguished Service Award on Dr. Parker in Washington on May 15, 1952. He was one of seven scientists in the Department to receive this high honor.

Everett Franklin Phillips
1878-1951

Everett Franklin Phillips was born in Hannibal, Ohio, Nov. 14, 1878 and died in Ithaca, N. Y., Aug. 21, 1951. It is rather trite in speaking of the past of some of our great men to state that their lives were dedicated to an ideal. We can say, however, without question, that Dr. Phillips dedicated himself to the service of apiculture. He was, in fact, one of the first men in this country with scientific training actually to engage in and to promote in all its phases the work of bee culture.

The picture unfolds shortly after the University of

EVERETT FRANKLIN PHILLIPS

Pennsylvania conferred the degree of Doctor of Philosophy in Zoology on Dr. Phillips and he was placed in charge of apicultural work in the Bureau of Entomology, U. S. Department of Agriculture. Apiculture was a relatively new and unknown subject to the young graduate but he soon became intrigued with all its phases, with all the unexplored fields that ran the gamut from bee behavior and pathology to the practical questions of the beeman.

Dr. Phillips throughout his life did much to make the scientific world cognizant of the importance of bee culture. At the same time he endeavored, and rather successfully, to get the practical beekeeper to take advantage of scientific research and information. One of his first moves was to comb Europe and the rest of the world for results of scientific work in apiculture that could be applied in this country. His early interest in the beekeeping literature led eventually to the establishment of the E. F. Phillips Memorial Beekeeping Library at Cornell University. Another result of his international interest in apiculture was freer exchange of information and ideas throughout the world by people interested in bee culture. Dr. Phillips made two important trips to Europe in 1926 and again in 1932. He visited France, England, Scotland, Germany, Austria, Yugoslavia and Russia. A recognized leader in his field, he was honored wherever he moved among beekeepers.

In a short obituary it is possible to mention only a few of Dr. Phillip's activities and accomplishments. In 1924 he became Professor of Apiculture at Cornell University and later Professor Emeritus of Apiculture until his death. Teaching and the collection of beekeeping literature occupied his time at Cornell rather than research. His students now occupy important posts in apiculture in all parts of the world. The beekeeping library at Cornell which was mentioned previously contains one of the finest collections of apiculture literature in the world and through patent grants Dr. Phillips made certain that the collection of literature would be well maintained after his retirement.

Dr. Phillips was the 47th president of the American Association of Economic Entomologists in 1933–34, and served on the editorial staff of the Journal. He was chairman of the Committee for Coordination of Entomology with the War Effort. Besides these he held many other important assignments in the Association.

He was a Fellow of the Entomological Society of America, member of the American Society of Zoologists and the Academy of Natural Sciences, Philadelphia. He was made an honorary and life member of many apicultural societies, both in this country and abroad. He was a Fellow of the Apis Club (International). Dr. Phillips is the author of hundreds of papers and bulletins on apiculture and author of one of the leading books on the subject entitled "Beekeeping."

An active part in Rotarian affairs was taken by Dr. Phillips. He was president of the Ithaca Club, District Governor, Chairman of the International Service Committee, director and vice president of Rotary International. He was also an active leader in such civic affairs as Community Chest and other welfare organizations.

The death of Dr. Phillips has left a gap in the ranks of beekeepers, a gap that may be supplemented but perhaps never filled.

Surviving Dr. Phillips is his immediate family—Mary Geisler Phillips, his wife; three sons, Everett Franklin, William Taylor and Howard Geisler. The name of Mary Geisler Phillips is also well known in the field of apiculture as she has written a number of delightful books and articles.

JAS. I. HAMBLETON
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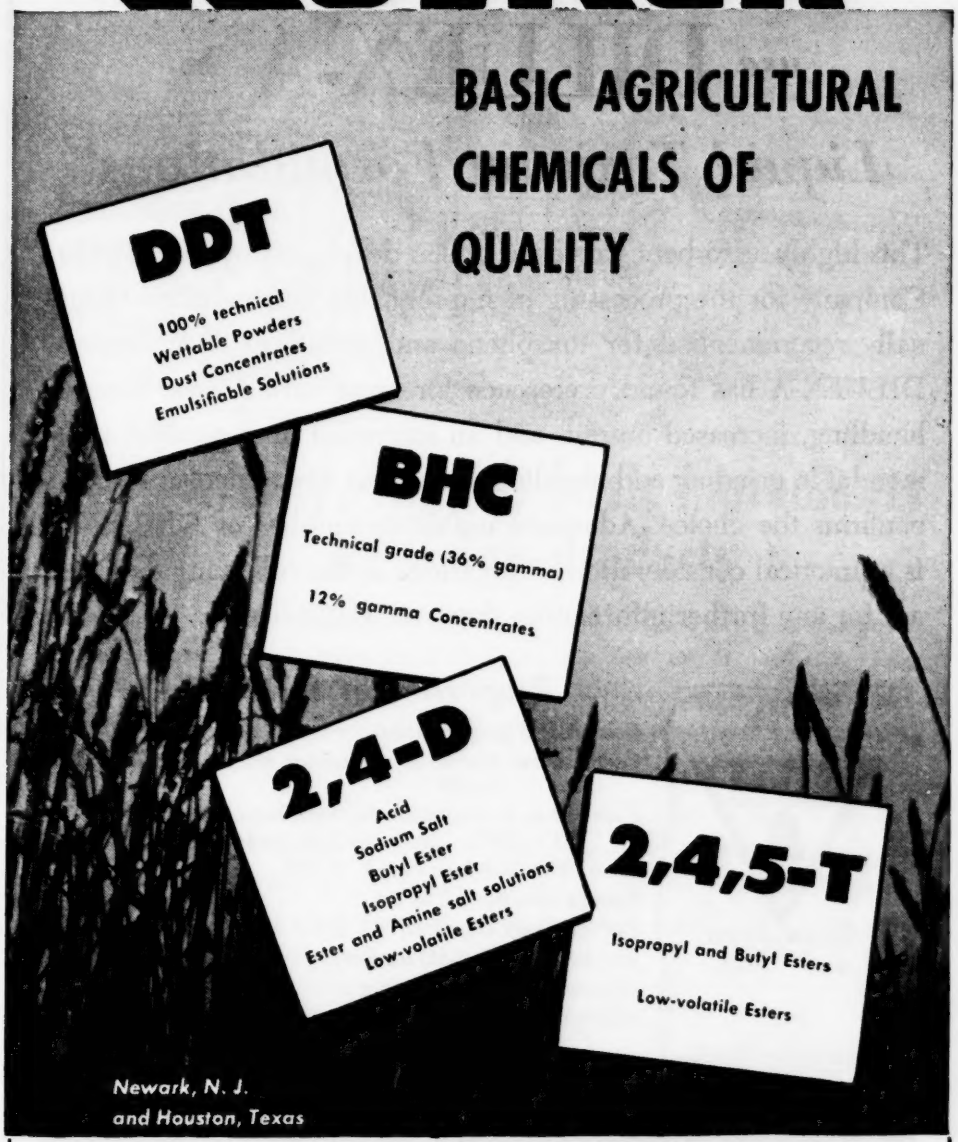

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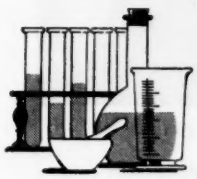

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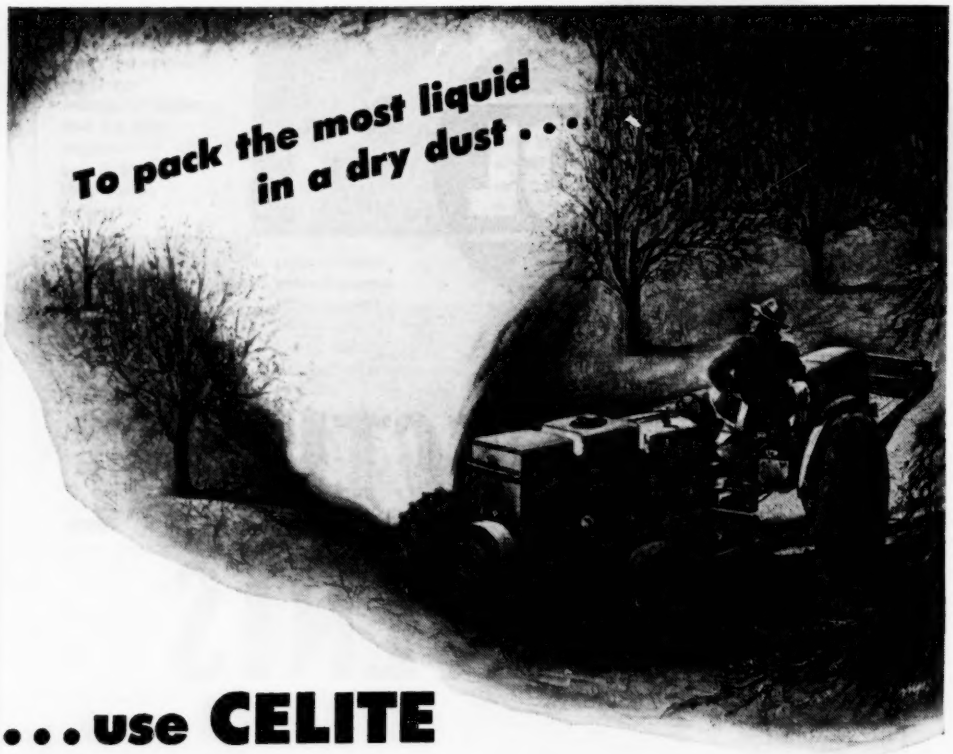

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